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


The New Journal of Laser Dentistry

The Journal of Laser Dentistry will continue to publish case reports provided by advanced proficiency candidates to help you with knowledge and ideas for your everyday practice. We will also encourage the submission of articles ranging from clinical practice to research studies.

Every issue will have at least one invited review of some aspect related directly to laser use in dentistry. These reviews are provided to update you with a series that will form the basis for understanding what is done in practice. You can refer back to these for years to come.

One significant advancement is that every article, whether it is a case study, a research report, or a scientific review, will be peer-reviewed. That means that at least two “peers” who are experts in the field have reviewed and critiqued the article prior to its revision and acceptance for publication. Submitted articles that fail to pass the peer review process satisfactorily will be rejected and you will never see them in print in the Journal.

We have a new editorial board that has been established to assist and advise us on the overall aspects of the Journal of Laser Dentistry. The editorial board members have already had a lot of input to bring us to where we are with our first issue in the new format. I am also building a panel of reviewers with a range of expertise relevant to our Journal. Steven Parker and Don Coluzzi will continue as associate editors responsible for the clinical case studies, Gail Siminovsky will continue as managing editor, and John Sulewski as consulting editor. Thank you to all of the above for agreeing to devote their time to their tasks. Thank you also to Don Pathoff, our outgoing editor for a job very well done.

I encourage you all to submit articles for consideration for publication. I also encourage feedback on what is good and what is not about the Journal. You can send your contributions directly to me at jdbf@ucsf.edu or via our executive director at laserexec@laserdentistry.org. Instructions to authors are published in every issue.

What qualifications do I have to be the editor of the Journal of Laser Dentistry? Firstly, a willingness to accept this challenge in my spare time. Secondly, I have been writing articles, reviewing, and guest editing now for more than 30 years for a variety of journals and proceedings. I am on four editorial boards of scientific journals, on the reviewer panels for others, and I review several manuscripts every month for other journals. Lastly, I was involved with research in laser dentistry quite a few years before the first laser was used clinically in the United States. I look forward to taking the Journal to the next stage of being an internationally recognized publication.

AUTHOR BIOGRAPHY

Dr. John D.B. Featherstone is Professor of Preventive and Restorative Dental Sciences at the...
Editor’s View

Dr. Michael Featherstone

Featherstone

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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SYNOPSIS

Dr. Emile Martin, current President of the Academy of Laser Dentistry, presents this guest editorial to describe the change to a new editor-in-chief and a new name and format for the Journal.

Benjamin Franklin wrote, “If you would not be forgotten as soon as you are dead, either write things worth reading, or do things worth writing.” It seems to me this is the goal of an organization’s journal. It is the chronicling of the journey of the organization. That process is certainly true of the Journal that is produced by the Academy of Laser Dentistry (ALD). Regardless of whether it was a newsletter to the membership or the newest incarnation of the full-color journal, it is the thread that binds and serves to perpetuate that we were here helping to foster the use and growth of laser therapy in dentistry.

This issue of the journal is the first under the editorship of John Featherstone. He carries forth the goal of making our journal the most prestigious in the field of laser dentistry that has been the hallmark of all who have come before him. John brings to the position substantial knowledge and esteem in the field of laser dentistry through his many years of experience in the academic community. We are certainly fortunate to have him accept the challenge of taking the journal to the next level. It is hoped that in the near future we will see articles in the journal receive the distinction of being found in appropriate online indexes of health sciences literature. Obtaining this status should help in attracting more submissions from the research and academic community. In addition, no effort is being spared to attract the best in clinical research and clinically relevant papers to maintain our position as the most clinically important journal in laser dentistry. The peer review process is continually being updated and refined to provide us with relevant information that we as readers can rely upon as being unbiased and with conclusions that are scientifically reliable.

With that in mind, the masthead of the journal is being changed to the Journal of Laser Dentistry. The feeling is that we want our journal to appeal to all areas of laser dentistry. We want to be inclusive to all the interests in laser dentistry. While the Journal is sponsored and produced by the ALD, the name change should assure all that the materials submitted and printed will pertain to all of the various players in the dental laser field, now and in the future.

No congratulations to the new editor can be complete without the mention of previous editors who have brought the journal to this point in time. The hard work and efforts of the following individuals, some of whom are still working on the editorial board, cannot be overstated as the leaders of the publishing effort. They include: Robert Fuchs, Ana Triliouris, Alan Goldstein, Leo Miserendino, Phil Hudson, Steven Parker, Don Coluzzi, and most recently Don Pathoff. The Academy is indebted to each of these individuals for their hard work and determination over the past 14 years to bring the Journal to its current level. On behalf of the ALD, thank you all and I hope you take pride in the continuing development of the project that you once led.

Finally I would ask the readers to remember what Franklin said and “either write things worth reading, or do things worth writing.” Your contributions to the field of laser dentistry will be much appreciated and your Academy will be better for your contribution to the literature. Contact John Featherstone (jdbf@ucsf.edu) or Gail Siminovsky (laserexec@laserdentistry.org) for any information that you might need about submissions.

Enjoy this first issue of the Journal of Laser Dentistry and the many others to come in the future.

AUTHOR BIOGRAPHY

Dr. Emile Martin is a graduate of the University of Virginia and Temple University School of Dentistry and currently serves as President of the Academy of Laser Dentistry. He has attained Advanced Proficiency in Nd:YAG and Holmium:YAG as well as Educator status in ALD and has used a dental laser in his private practice in Syracuse, New York since 1994. Dr. Martin is a Diplomat of the American Board of Oral Implantology, holds Mastership in the Academy of General Dentistry, is a Past President of the American Academy of Implant Dentistry and a Past President of the American Academy of Dental Group Practice. He serves as a part-time instructor in St. Joseph’s Hospital General Practice Residency program as the Chief of the Treatment Planning Department and lectures on dental laser and dental implant topics.

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The Use of Lasers in Bone Surgery

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SYNOPSIS
The use of suitable laser wavelengths in the cutting and ablation of bone during dentoalveolar surgery can offer distinct advantages over rotary instrumentation. It is essential to use the correct laser wavelength and power parameters to maximize predictable outcomes for bone surgery in dentistry. This article presents a review of this topic and provides examples from clinical practice.

BONE STRUCTURE
Bone is a connective tissue derived from hyaline cartilage whose matrix, under the influence of calciferol, has been hardened by the deposition of calcium and phosphate to form a carbonated hydroxyapatite-like mineral, a carbonate substituted form of Ca_{10}(PO_4)_{6}(OH)_2, as the ground substance. Collagen remains the primary fibre in the matrix as it is in hyaline cartilage. Histologically, bone is composed of units termed Haversian systems or osteons in which concentric rings of osteocytes are arranged around a central blood vessel. The blood supply is via an arteriole-venule plexus within the peripheral periosteum, or via vessels contained within the bone substance. Cross-linkage between central canals is provided by Volkmann's canals. This matrix is maintained by osteocytes, the characteristic cells of bone.

Of concern to the dental surgeon, the dentoalveolar processes of the maxillary and mandibular bones are composed of an outer cortical plate, covered by periosteum and an inner complex of trabecular or cancellous bone. The cortical plate of the mandible is thicker than that found in the maxilla and remains fairly constant during adult life. However, the volume of cancellous bone in both jaws will reduce with time, following tooth extraction, indicating the purpose of this tissue as being supportive of the natural dentition. With the exception of the central neurovascular bundle, the mandible derives its blood supply from periosteal vessels and this assumes greater relevance with age, due to reduction in diameter in the inferior dental vessels. The extensive blood spaces found in the maxilla provide a more homogeneous blood supply in this bone, deriving from a central maxillary artery source. It therefore follows that, for surgical procedures that require the cutting or ablation of bone, care should be given to maintaining a contiguous relationship between periosteum and bone in the mandible, to prevent ischaemic atrophy.

BONE HEALING
Following injury or surgery and in the absence of infection, the healing of alveolar bone is similar to that of osteoid tissue elsewhere in the skeleton. Early blood clotting allows a matrix for cellular and biochemical activity, whereby predominant osteoclastic action removes any damaged or dead mineralized tissue. This resorption stage will be longer in those cases where extensive damage has occurred, either due to trauma or thermal shock. Following this, early growth of new bone occurs, through osteoblastic activity, to form a callous and later, woven bone, which over time is gradually remodeled to mature bone.

LASER ABLATION OF BONE
“Conventional” bone cutting with a bur or bone saw may result in a substantial temperature increase which far exceeds the threshold for protein breakdown and leads to possible sequestration of damaged bone elements. Equally, studies on the effects of commercially available Nd:YAG and CO₂ lasers on bone show carbonisation and other structural damage. Consequently, a “best practice” approach to bone ablation and cutting would suggest the need for a modality that would produce clinically acceptable rates of cutting without overheating. The current

ABSTRACT
The development of laser use in surgical dentistry has expanded to include all oral hard tissues, with accepted protocols for selected wavelengths being adopted. The purpose of this article is to demonstrate the composite nature of alveolar bone, the microstructure and processes commensurate upon bone damage, together with a review of the literature surrounding the applicable adjuncts of laser energy in the ablation of this tissue.
mid-infrared laser wavelengths, Er, Cr:YSGG (2780 nm) and Er:YAG (2940 nm), appear to offer such modalities.\(^\text{13}\)

As with other hard tissue interaction, it is essential to maintain a co-axial water spray to prevent heat damage which would delay healing. Studies of the rate of thermal denaturation of collagen, a major component of bone tissue, show that above a critical temperature (74° C), the rate of collagen denaturation rapidly increases, causing rapid coagulation of tissue.\(^\text{14-15}\) In general at temperatures above 60-80° C, collagen denaturation, coagulation, and necrosis are initiated. At temperatures above 100-300° C, there is the onset of dehydration, followed by carbonisation of proteins and lipids. Above a few hundred degrees, the protein of bone is pyrolised, leaving a carbon residue and possible structural changes in the mineral components.

The two applicable lasers for bone ablation are the Er:YAG (2940 nm) and the Er,Cr:YSGG (2780 nm) wavelengths. Both Er,Cr:YSGG and Er:YAG laser wavelengths are well absorbed in water, with the Er:YAG being somewhat more strongly absorbed in water than the Er,Cr:YSGG. This absorption in water is due to a relatively broad water band around 3,000 nm.\(^\text{16-19}\) In addition, there is a small absorption around 2,800 nm by the hydroxyl group of the (carbonated) hydroxyapatite mineral of the tissues\(^\text{16,20-21}\) but this is far outweighed by the whole-water effects.

When incident laser energy is directed onto bone, it is absorbed by the prime chromophore, water. For both Er:YAG and Er,Cr:YSGG laser wavelengths this energy is absorbed primarily by the water and is rapidly converted to heat, which causes superheating and a phase transfer in the subsurface water, resulting in a disruptive expansion in the tissue. Early study into the effect of the Er:YAG laser on bone showed that, like enamel and dentin ablation, tissue cutting is a thermally induced explosive process.\(^\text{22-23}\) Through this mechanism, whole tissue fragments are ejected and a hole is cut in the bone, with little or no alteration to the mineral itself.

![Dental Enamel Absorption](image.png)

**Figure 1:** Absorption curve of enamel (carbonated hydroxyapatite (HA)) and emission wavelengths of the Er,Cr:YSGG, Er:YAG, and CO\(_2\) lasers. Carbonated HA exhibits a small peak at approximately 7,000 nm, coincident with (CO\(_3\))\(^{2-}\) radical absorption. Water absorption is shown as a dotted line.

The use of erbium lasers in dentoalveolar surgery represents a less traumatic experience for the patient when compared to the intense vibration of the slow-speed surgical bur. Ablation threshold values of 10-30 J/cm\(^2\) have been recorded for bone of varying density.\(^\text{24}\) In the author’s clinical experience, with maxillary alveolar bone surgery, the speed of laser cutting is comparable to that of a surgical bur and slightly slower in the mandible, reflecting the greater mineral content of the latter’s cortical bone. Such statements are subjective, especially as one study\(^\text{25}\) reports slower cutting rates, although it does draw reference to bone ablation in the third molar region. What may be of greater relevance is the ability to carry out laser ablation within a clinically acceptable time frame. It is considered important that power parameters and water spray levels are adequate in order to prevent a “stall-out” effect of debris (where ablation products are allowed to accumulate and...
absorb laser energy). Laser settings of 350-500 mJ / 10-20 Hz (average power range 3.5-7.0 Watts) with maximal water spray appear to produce good ablation rates.

The ablation threshold for average bone is approximately 12-20 J/cm². As an example, Table 1 shows how easily that given fluence can be far exceeded when a beam diameter is used that is too small and/or the energy per pulse is too high.

It is essential, therefore, that correct power parameters are adopted so as not to produce unwanted heat effects in the target tissue site.

The poor haemostatic effect of current commercially available Er:YAG lasers can be used to advantage in the ablation of bone to ensure blood perfusion of the surgical site (Figures 2-3).

However, the ablation process using a pulsed laser and water spray results in a considerable spatter of blood, and precautions (eye protection and mask) are recommended. An additional risk may be the creation of an air embolism in the tissue, due to the air-induced water spray, although a review of the literature has not revealed an association. The ablation of bone using laser energy is associated with a level of noise, which represents the explosive interaction with chromophores. This has been measured in one study at between 99 and 121 dB. However, in the author’s experience, such sound level does not give cause for patient concern.

Scanning electron microscope analysis of the cut surface of bone (Figures 4-5) reveals little evidence of thermal damage, and any char layer appears to be restricted to a minimal zone of 20-30 µm in depth. Studies into the healing of laser-treated bone support the contention that the reduced physical trauma, reduced heating effects, and reduced bacterial contamination lead to uncomplicated healing processes when compared to conventional use of a surgical bur.

**Table 1: Relationship between laser beam diameter, energy per pulse, and resulting fluence values.**

<table>
<thead>
<tr>
<th>Beam Diameter</th>
<th>100 mJ</th>
<th>250 mJ</th>
<th>500 mJ</th>
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<tbody>
<tr>
<td>300 µm</td>
<td>141 J/cm²</td>
<td>353 J/cm²</td>
<td>707 J/cm²</td>
</tr>
<tr>
<td>600 µm</td>
<td>35 J/cm²</td>
<td>88 J/cm²</td>
<td>175 J/cm²</td>
</tr>
<tr>
<td>1000 µm</td>
<td>13 J/cm²</td>
<td>32 J/cm²</td>
<td>64 J/cm²</td>
</tr>
</tbody>
</table>

**PAIN ASSOCIATED WITH BONE ABLATION**

The classic tissue response to trauma such as surgery, as with infection, is inflammatory reaction. The five characteristics of calor (heat), dolor (pain), rubor (redness), tumour (swelling), and loss of function can result in postoperative oedema, pain, and trismus. It is considered that the level of kinin production following surgery plays a large part in the degree of pain and swelling. Anecdotally, the patient response following bone ablation with lasers appears to be one of greater comfort, compared to surgery carried out with a rotary bur. The number of investigations into this subject appears to be small. However, in a randomised
controlled clinical trial, the Er:YAG laser was compared with a surgical bur for removal of partially erupted lower third molars. Patients were allocated randomly to be treated by either laser or bur. A total of 42 patients (laser = 22; bur = 20) were treated. The study reported a greater reduction in the range of mouth opening after laser than after bur treatment, presumably due to the longer operating time taken although postoperative pain was more common after bur treatment.

**CONCLUSION**

The use of suitable laser wavelengths in the cutting and ablation of bone during dentoalveolar surgery can offer distinct advantages over rotary instrumentation. The reduction in heat production and thermal collateral damage can result in a less aggressive inflammatory process in the host tissue. In addition, the reduction in tactile stimulation during surgery can be deemed less unpleasant for the patient. To avoid damaging effects, there is only a narrow range of laser energy recommended for ablation of bone tissue. It is essential to use the correct laser wavelength and power parameters to maximise predictable outcomes for bone surgery in dentistry.

**AUTHOR BIOGRAPHY**

Dr. Steven Parker studied dentistry at University College Hospital Medical School, University of London, UK and graduated in 1974. He is in Private Practice in Harrogate, UK. He holds Fellowship and Diplomate status with the International Congress of Oral Implantologists. Dr. Parker has been involved in the use of lasers in dentistry since 1990. Prior to joining the Academy of Laser Dentistry in 1993, he was President of the British Dental Laser Association. He joined the Board of Directors of the Academy in 1996 and became chair of the International Relations Committee. From 1999 through 2004, he was chair of the Committee for Proficiency Recognition and co-editor of Wavelengths, the former journal of the Academy of Laser Dentistry. He was awarded the Leon Goldman award for Excellence in Clinical Laser Dentistry by the Academy in 1998. In addition, Dr. Parker holds Advanced Proficiency status in multiple laser wavelengths and completed the Academy Educator Course at the University of California – San Francisco in 2000. He is an ALD-Recognised Standard Proficiency Course Provider. He has held consultancies with multiple laser companies and has presented courses, lectures, and workshops worldwide. He has authored numerous articles on the use of lasers in dentistry, including a chapter “The Use of Lasers in Fixed Prosthodontics” in the October 2004 Dental Clinics of North America. Dr. Parker was the 2005 President of the Academy of Laser Dentistry. Dr. Parker may be contacted by e-mail at thewholetooth@easy.net.co.uk.

**Disclosure:** Dr. Parker has no current affiliations with any company.

**REFERENCES**

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INTRODUCTION
The resolution, acquisition rate, and penetration depth of OCT systems have significantly improved in recent years. We have successfully applied many of these new OCT developments to dental imaging (Figure 1). Our work has been focused on studying instrument parameters that determine OCT image characteristics of teeth and oral tissues. System components that we have studied include wavelength and power of the light source used, collection optics and lens systems, methods used to modulate the interferometer reference arm, handpiece designs that minimize motion artifacts, and software algorithms to improve image quality. We improved axial resolution of our dental OCT prototypes from 13 to 20 µm and imaging time from 45 to 5 seconds.\(^{4,9}\)

OCT measures the reflections of light from tissues based on the principles of interferometry. Light from a low-coherence source is divided and reflected from a reference mirror and the tissue. When the path length of light from the reference mirror is the same as the tissue, an interference fringe is detected. Because the reference mirror is moved in known increments, the position of the reflected light within the sample can be determined. The magnitude of the reflected signal is determined by the optical scattering properties of tissues. The sample arm is raster-scanned across the tooth or tissue surface and a two-dimensional, cross-sectional image is obtained.

OCT IMAGING OF COMPOSITE RESTORATIONS
We investigated the capacity of OCT to image teeth and dental restorations using 9 extracted teeth from patients with dental caries. OCT images consist of successive interferometric signals that are compiled into a two-dimensional image. OCT is noninvasive and uses wavelengths of light in the infrared region (850-1550 nm) that have considerable depth of penetration in tissue but no known detrimental biological effects.

Results in a small number of patients suggest that OCT images of the soft tissue surrounding endosseous dental implants differ in health and disease. Dental OCT provides noninvasive, high-resolution assessments of the oral microstructure in cross-section providing information that is similar to histological sections. Finally, our studies have shown that dentists, previously unfamiliar with OCT images, were easily trained to interpret clinical findings with a high degree of accuracy and inter-examiner reliability.
premolars, with composite restorations placed into the facial surfaces. The preparations were varied to include 3 teeth with axial cavity depths of 1, 2, and 3 mm. Cavosurface margins (n = 18) included 5 shallow bevels (0.5 mm), 3 deep bevels (1.5 mm), 7 nonbeveled butt joint margins, and 3 margins with extraneous composite material beyond the margin (flash). A reference point was marked on each tooth and OCT images were made in triplicate along the long axis of the mid-facial surface. The teeth were subsequently sectioned at the reference point and photomicrographs corresponding to the OCT imaging plane were prepared. To evaluate the accuracy of the OCT images, transparent overlay outlines of the composite restorations, dentinoenamal junction (DEJ), and external tooth contours were made from the photomicrographs using Adobe Photoshop software. The overlays were superimposed onto the corresponding OCT image and differences were quantified. The superior and inferior borders of the restorations were imaged with fidelity in all of the OCT images. Marginal characteristics were accurately imaged in 17 of the 18 images. The axial margins were not imaged in any of the restorations with axial depths of 3 mm. The axial depths of these preparations were selected to represent typical restorations (1 and 2 mm) and maximal expected axial depth (3 mm). Minimal spatial distortion of the axial wall was noted in the restorations with axial depth of 1 and 2 mm. This distortion corresponded to an index of refraction of approximately 1.5 for the composite material.13 As a result of these findings, we incorporated software controls into our clinical prototype to allow interactive input to correct for index of refraction artifact.

During field epidemiologic studies when decayed, missing, and filled surfaces (DMFS) are quantified, it is often impossible to distinguish occlusal surfaces that have resin covering the fissures as either being sealed or having a preventive resin restoration or a posterior composite on that surface. Consequently, we investigated the capacity of OCT to accurately discriminate occlusal sealants and composite restorations. Twenty-one dentists were asked to interpret OCT images of 9 premolars that either were not restored, contained an occlusal sealant, or were restored with a composite restoration. Following a brief training period, these dentists evaluated the OCT images following a randomized blind protocol. The sensitivity of OCT to discriminate composite and sealants was greater than 0.92 while the specificity of discrimination was greater than 0.94. The capacity of OCT to discriminate sealants from nonrestored occlusal surfaces was slightly less (sensitivity 0.88; specificity 0.86), but still within a clinically acceptable level. We concluded that OCT represents a safe, reproducible method to discriminate filled versus sealed tooth surfaces, thereby increasing the accuracy of DMFS assessments. Inter- and intra-rater reliability as measured by the kappa statistic also revealed excellent performance by dentists using this new imaging technology (kappa = 0.82 to 1.0). This study also demonstrated that dentists who were previously unfamiliar with OCT images could be trained to interpret the images.14

Using three-dimensional OCT imaging, we estimated wear and evaluated the structural integrity of composite resin restorations as an additional component of an ongoing Institutional Review Board (IRB)-approved study of posterior composite materials in adult dentate patients. In this study, composite wear was assessed using a Moffa-Lugassy (M-L) scale, a method that is commonly used to indirectly determine the loss of anatomical form and wear in posterior composite restorations. Impressions of the composite are compared to a standard set of cylinders in which the center portion is offset to simulate the loss of composite resins in a restored tooth. The M-L system has been shown to identify composite wear and allow reproducible quantification up to 25 micrometers.15

We used OCT to generate contour maps of the restoration surface that quantified volumetric loss or surface changes in the restorative material over time. We analyzed OCT composite contour maps in 4 premolars with composite resin restorations at baseline, insertion, and 12 months. Wear estimates as determined by the OCT contour maps correlated well with the value as determined by the traditional method of measuring composite wear, the M-L scale (r = 0.86; p < 0.05). All of the OCT images recorded changes in the restoration surface that occurred with occlusal function. One image demonstrated a region of catastrophic failure. This abnormality (catastrophic failure) was not clinically or radiographically visible, indicating OCT has the potential to detect restorative defects earlier than current diagnostic methods.16

OCT IMAGING OF CROWN MARGINS

In a small patient-oriented study, we investigated the potential of OCT to assess the internal structure and marginal adaptation of cemented crowns.17 Cross-sectional images were made in duplicate on the mid-facial surface of cemented functional crowns with well-adapted margins and no clinical evidence of recurrent caries. We imaged in vivo 8 teeth (3 posterior, 5 anterior) with porcelain-fused-to-metal coronal restorations. The internal structure and marginal adaptation were clearly visualized in all the teeth imaged. In 4 of the
crowns, characteristic image layers that corresponded to incisal and body porcelain were visualized. As applied to the imaging of functional crowns, this study showed that OCT has the potential to improve accuracy of marginal assessments as compared to radiographic imaging. Only the mesial and distal aspects of crowns are visualized in radiographs; OCT offers advantages in imaging the crown adaptation on any aspect of the coronal surface with improved accuracy as compared to tactile exploration. An OCT image of a crown is shown in Figure 2.

OCT IMAGING OF THE PERIODONTIUM

It is also feasible to use OCT to depict soft and hard tissue boundaries of the periodontium. We have visualized and measured soft tissue thickness, sulcular depth, and length of the periodontal attachment around teeth in OCT images. Using porcine jaws, we measured sulcular depth in duplicate using standard periodontal probing techniques. OCT images were prepared in duplicate using a prototype system with a 1310-nm wavelength light source, 140 µW, 95 dB dynamic range, 0.46 numerical aperture resulting in images that were 10 mm long and had an axial resolution of 17 µm. The hemimandibles were subsequently embedded in clear acrylic, transversely sectioned at the reference points, and photomicrographed. The DEJ, cementoenamel junction (CEJ), and sulcus depth were detected in all OCT images and corresponded to their locations in the photomicrographs. Probing depths as measured with a conventional periodontal probe were strongly correlated to those obtained in OCT images for buccal sites (r = 0.88; p < 0.05) and moderately correlated on the lingual sites (r = 0.57; p < 0.05).

We also correlated clinical periodontal probing depth to sulcular depth as measured in OCT images in a small study of 5 healthy human volunteers. The mid-facial surface of 14 nonrestored teeth (1 mandibular and 3 maxillary incisors, 4 maxillary and 6 mandibular premolars) were imaged using a prototype OCT system (1310-nm wavelength light source, 14 µW, 95 dB dynamic range, 0.46 numerical aperture). Following OCT imaging, probing depths were measured in duplicate using a Michigan 0 probe. Important anatomic features including soft tissue surface contour, gingival crest, periodontal sulcus, and DEJ were identified in OCT images of all of the teeth examined. The CEJ was identified in 18 of the 28 images; the alveolar bone was presumptively identified in 20 of the 28 images. Probing depth as measured in OCT images was strongly correlated to probing depth as measured by conventional probing measurement (r = 0.83; p < 0.05). Restoration margins and internal restoration contours were visualized and did not interfere with interpretation of OCT images of soft tissue landmarks.

An all-fiber-optic clinical OCT system was used to obtain 12-millimeter occluso-apical OCT images that were made in duplicate at the mesial facial line angle of the premolars in 4 healthy volunteers. This system employed a 6-mW, 1310-nm light source and produced images that had an axial resolution of 21 µm. Characteristic signals representing the sulcus and attached tissues were identified in all images. Premolar sulcular depth as determined from the OCT images ranged from 1.1 to 2.5 mm and was strongly correlated with probing depth (r = 0.88; p < 0.05). We defined attached tissues in the OCT images by uniform signal intensity with no discernible tissue interfaces, extending from the base of the sulcus to the alveolar crest. Attached tissues in the OCT images ranged from 1.1 to 3.8 mm. The lowest values for attached tissues were found in 3 teeth with coronal restorations. Signals presumptively identified as the alveolar crest were identified in 60 of the 64 images. The thickness of the gingiva covering the alveolar crest ranged from 0.4 to 1.4 mm. Two teeth had characteristic signals representative of the root surface covered by a thin mucosal tissue; these sites were presumptively identified as fenestration defects. The results of this study demonstrate the capacity of OCT to determine gingival thickness and the shape and contour of the alveolar crest. Visualizing these...
anatomical features represents a significant contribution to periodontal surgical treatment planning.

OCT is uniquely suited to clinically evaluate implant health because it provides high-resolution, cross-sectional images of the soft tissues that surround implants. Histological studies in animals have shown that gingival connective tissue forms a scar-like fibrous connective tissue adjacent to titanium implant surfaces, while peri-implantitis is characterized by disorganized connective tissue containing more vascular elements. Our preliminary data demonstrate that in OCT images of healthy implant sites, collagen appears well-organized, and because of its birefringent nature, produces a characteristic high OCT signal intensity. OCT images of soft tissue surrounding failing implants are significantly different from images of healthy implant sites and are characterized by linear signal deficits, low-intensity collagen signals, and pronounced increases in vascular elements (Figures 3 and 4).

Based on these findings, we conducted preliminary studies to determine whether OCT can be used clinically to detect early peri-implantitis with greater sensitivity than current diagnostic methods. We used a 6-mW, 1310-nm conventional OCT system that produced images with 20 µm axial resolution and image contrast ratio of 0.15 to assess the feasibility of OCT for the diagnostic evaluation of peri-implant soft tissues; we imaged 8 implants in 3 patients. OCT images of failing implants characteristically differed from healthy implant sites. Based on these findings, we anticipate that by examining a larger patient sample, we will establish the best system parameters to characterize peri-implant tissues and demonstrate measurable differences in healthy and diseased implant sites.

FUTURE DIRECTIONS

The axial resolution, imaging depth, and speed of current OCT systems are limited by the bandwidth and the optical power of the light source. Current OCT systems are usually time-domain instruments linearly ordered (that is, form birefringence). In our polarization-sensitive (PS-OCT) system, vertical and horizontal polarized signals were detected in two channels and images were reconstructed by combining the signals, thereby revealing with greater detail the structural features of enamel and dentin. An additional advantage of polarization-sensitive OCT as compared with conventional OCT is significantly improved signal-to-noise ratio and image contrast.22 In polarization-sensitive OCT images of occlusal caries, the structural detail of caries and the dynamic nature of the carious lesion were revealed. Regions of demineralization had low signal intensity, while regions of remineralization were characterized by high signal intensity. Similar findings have been reported by Fried and coworkers who demonstrated that PS-OCT is well suited for the imaging of interproximal and occlusal caries and early root caries, and for imaging decay under composite restorations.21-23

IMPROVING OCT IMAGE INFORMATION

We also investigated methods to improve dental OCT capabilities by combining additional imaging and detection schemes with conventional OCT. We added a functional component by combining a Doppler technique and OCT, producing images (Figure 5) that detected blood flow rates in superficial labial vessels.16-19 We also investigated several instrument schemes to produce polarization-sensitive images. Enamel and dentin exhibit structural anisotropy because the macroscopic orientation of enamel rods and dentinal tubules are

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FUTURE DIRECTIONS

The axial resolution, imaging depth, and speed of current OCT systems are limited by the bandwidth and the optical power of the light source. Current OCT systems are usually time-domain instruments
constructed using discrete components and bulk optics in free space. These systems are complex, have large footprints, and are of high cost. The major limitation of time-domain OCT systems is that they use a single-point motorized scanning mechanism to acquire the tomographic image. This limits the imaged region of interest to a few millimeters for most dental applications. Mechanical scanning not only prolongs imaging time but also represents the major challenge in devising a widely applicable clinical dental imaging system. Recently new techniques known as Fourier domain OCT have been investigated. Fourier domain OCT provides higher acquisition speed and better signal-to-noise ratio than traditional time-domain methods.

Authors Otis and Zhu have recently collaborated with Dr. Boon-Siew Ooi of Lehigh University who has pioneered the fabrication of a broad luminescent bandwidth light source that can be coupled with an on-chip spectrometer. We will integrate the essential elements of this novel light source and the essential components of an OCT system, creating a 4-channel Fourier domain OCT system on a chip (OCT-SOC). The total chip size of this new prototype will be less than 2 x 3 mm. When developed, the estimated production cost for a fully packaged, single-element OCT-SOC is expected to have a unit cost of less than $200.00. OCT-SOC will significantly increase the scanning throughput for a dental OCT system, resulting in faster image acquisition, greater imaging depth, and increased axial resolution to approximately 10 μm. Compared with the bulk optics and discrete components of current OCT systems, the OCT-SOC is anticipated to be significantly smaller, lighter in weight, and lower in cost, making OCT dental imaging systems a reality.

**AUTHOR BIOGRAPHY**

Dr. Linda Otis is presently Professor of Oral and Maxillofacial Radiology at the University of Maryland, Baltimore College of Dental Surgery, Department of Diagnostic Sciences and Pathology. She began her pioneer work in the field of Optical Coherence Tomography in dentistry in 1991 at the University of California, San Francisco and in 1994 at the Medical Technology Program at the Lawrence Livermore National Laboratory in Livermore, California. She lectures nationally, has authored many research papers, and has published numerous articles in peer-reviewed dental journals. Dr. Otis may be reached via e-mail: lotis@umaryland.edu.

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**Disclosure:**

Dr. Otis is Vice President of Clinical Research for Lantis Laser Inc., a company formed to commercialize the application of novel technologies in the dental industry, including OCT Dental Imaging. Dr. Otis is named on three OCT-related patents, and has been the recipient of research grants from the U.S. Department of Health and Human Services National Institutes of Health for her work.

**REFERENCES**


CASE REPORT

Elimination of a Venous Lake on the Vermilion of the Lower Lip Via 810-nm Diode Laser

Lawrence A. Kotlow, DDS, Albany, New York


INITIAL DIAGNOSIS

A venous lake or pool presents as a bluish, soft, discrete, painless nodule beneath the epithelium of the lower lip. Although this lesion is usually seen in individuals over 40 years of age, this patient presented with it at age 8 (Figure 1). There is no gender predilection, and in many instances the lesion is located on the lower lip mucosa or vermilion, or on the buccal mucosa. Pressure on the feeder vessel will produce blanching, and the lesion is almost never larger than 6 mm in diameter. These types of lesions are usually observed as a single, perhaps tortuous, dilated vein located superficially beneath the surface epithelium, above the striated lip muscles. This lesion is also known as a traumatic angiomatous lesion. It differs from hereditary hemorrhagic telangiectasias and similar developmental disorders by the pattern and increased numbers of vascular lesions associated with more complex disorders.

PRETREATMENT

A. Outline of Case

1. Clinical Examination

An 8-year-old Caucasian female presented for an initial dental examination. Her oral evaluation indicated an age-appropriate complement of teeth, no dental decay, and normal occlusion. There were no intraoral lesions or other abnormalities. Her present and past medical histories were unremarkable. Examination of the external head and neck area revealed a small elevated blue lesion in the middle of the lower lip. The lesion was consistent with the diagnosis of a venous pool as described above.

SYNOPSIS

This article describes the successful removal of a venous lake lesion from the lip of an 8-year-old using an 810-nm diode laser. The procedure was successful and the follow-up visits showed continued healing.

ABSTRACT

A venous lake or pool often appears at the site of an injury to the lower lip. In most instances, this condition may be found in adults over the age of 40. This case presents a lesion which developed due to trauma in an 8-year-old patient. Treatment using an 810-nm diode laser ablated the lesion with topical anesthetic only.

2. Radiographic Dental Examination

The radiographs of the patient were consistent with a normal developing dentition.

3. Past Oral History

The patient had sustained a slight trauma to the lower lip approximately one year ago. As the result of the accident, the small lesion developed in the middle of the lower lip (Figure 1). According to the child's mother, the patient had been examined previously by a plastic surgeon for evaluation of the lesion. The plastic surgeon had recommended leaving the lesion alone. At this time, she consulted with my office to explore possibilities for eliminating the lesion. Both the child and the mother felt the lesion was unsightly and seemed eager to have it removed.

B. Diagnosis and Treatment Plan

1. Diagnosis

The lesion was consistent in history...
and appearance as a venous lake (Figure 2).

2. Informed Consent
A discussion was held with the parents and the child. They were advised that it was impossible to guarantee the final results of treatment. Possible outcomes included the successful removal of the lesion; inability to completely remove the lesion; and permanent scarring at the site (though this was considered unlikely).

3. Treatment Recommendation
Removal of the lesion using an 810-nm diode laser using topical anesthetics.

4. Alternatives to Treatment
Seek additional consultations with plastic or oral surgeons. Accept the prior medical recommendation to leave the lesion untreated.

5. Indication for Treatment Using an 810-nm Diode Laser
The source of the lesion is a feeder vessel that extended an appendage into the epithelium of the lip. With its ability to be absorbed by hemoglobin, the 810-nm diode laser targets the small vessel that delivers blood to the lesion. Thus the laser has the potential to destroy the lesion by shutting down the extension of the feeder vessel without damaging the lip or scarring the area of the lesion. There is little collateral damage with treatment with an 810-nm diode laser. The lesion can be removed with immediate results using a minimally invasive treatment under a topical anesthetic agent.

6. Contraindications
None in this case. Potential for bleeding was discussed during the informed consent discussion. However, this was not considered to be a contraindication.

TREATMENT

A. Objective
Ablate the venous pool without leaving any undesired remnants of the lesion.

B. Laser Operating Parameters
A diode laser (DioDent™, HOYA ConBio, Fremont, Calif.) was used to remove the lesion.
- Power setting: 0.6 Watt
- Delivery system: 400-micron fiber
- Emission mode: CW (continuous wave)
- Wavelength: 810 nm
- Total time: Approximately 90 seconds from start to finish

C. Treatment Delivery Sequence
- Safety glasses appropriate for the 810-nm diode laser were placed on the seated patient.
- The assistant then put on safety glasses.
- A topical anesthetic agent (TAC 20%) was placed on the target area for approximately 3 minutes.
- The laser fiber was cleaved and tested for a good surgical beam.
- The entire surgical field was viewed through a dental operating microscope (Global Surgical Corporation, St. Louis, Mo.) fitted with safety lenses to protect the dentist’s eyes.
- High-speed suction was turned on.
- For the initial treatment the fiber was not initiated, allowing the area to be heated slowly.

- The non-initiated tip was moved in a circular motion approximately 2-4 mm above the lesion for about 45 seconds.
- The tip was then initiated using a small piece of blue articulating paper. The author’s clinical observation was that this allowed the target tissue temperature to rise faster without causing the tip to overheat.

Figures 3-5: Progressive appearance of the lesion during ablation by the diode laser.
The fiber was then brought into light contact over the area containing the lesion. The site was then abraded until the area turned white where the blue lesion had been present. This took approximately 45 seconds of intermittent contact until the desired results were achieved (Figures 3-5).

D. Management of Complications
There were no complications. The area appeared white without any signs of bleeding. The patient did not appear to have any significant discomfort during or immediately after the treatment.

E. Postoperative Prognosis
The immediate postoperative appearance indicated total ablation of the lesion (Figure 6).

F. Treatment Records
All operating parameters were noted in the patient’s chart. Photographs of the pre- and post-treatment conditions of the area were taken and placed in the digital record of the child. The procedure was videotaped using a HD video camera attached to the microscope.

G. Postoperative Care and Instructions
The parents were advised to give appropriate pain medication if the child indicated that she was having discomfort, and to call if any bleeding or concerns developed. The procedure was completed in a morning appointment and a follow-up phone call was made that evening. No problems had occurred and the patient was comfortable.

The patient was appointed to return in 2 weeks for an observation of the area. The appearance is shown in Figure 7. (Normally the patient would be seen after 1 week; however, the family was leaving for vacation in 2 days.)

Figure 6: Appearance of the treated area immediately post-treatment.

Figure 7: Appearance of the treated area 13 days post-treatment.

Figure 8: Appearance of the treated area 3 months post-treatment. Area remained free of lesion.

FOLLOW-UP CARE
A. Side Effects and Complications
There were no undesired side effects or complications of the treatment.

B. Assessment of Treatment and Healing
The patient returned for evaluation of the area on day 13. There were no signs of either the lesion or scarring (Figure 7). Both parents and the child were extremely happy with the results.

C. Long-Term Results
Excellent. The area was completely free of the lesion. Follow-up will occur at routine periodic preventive maintenance visits. The appearance of the treatment area three months after the procedure is shown in Figure 8.

AUTHOR BIOGRAPHY
Dr. Lawrence Kotlow is a Board Certified Pediatric Dentist and has a private practice in Albany, New York. He has received Advanced Proficiency Certification in Er:YAG Laser and Standard Proficiency in diode laser from The Academy of Laser Dentistry. He contributed a chapter in the October 2004 issue of the Dental Clinics of North America on using the erbium laser in pediatric dentistry, and has written many articles on using lasers in pediatric dentistry. Dr. Kotlow may be reached via e-mail: KIDDSTEETH@aol.com.

Disclosure: Dr. Kotlow lectures and conducts instructional courses for HOYA ConBio and receives an honorarium for his seminars.

REFERENCES
Advanced Proficiency Case Studies

The following cases were presented by three recent successful Advanced Proficiency candidates during the last two Academy of Laser Dentistry annual conferences.

1. Dr. Alfred Wyatt uses an Er:YAG laser for two clinical cases. In the first, the laser was used without anesthesia for removal of carious lesions in two anterior teeth, and then composite resin restorations were placed. A second pediatric patient received similar treatment for removal of carious lesions in two molars.

2. Dr. Raminta Mastis utilizes an Er:YAG laser for esthetic crown lengthening. This wavelength is ideal for removing and recontouring both the gingiva and the underlying osseous structures to achieve the desired new tooth proportions prior to restoration.

3. Dr. Alberto Trigas Damian utilizes an Er:YAG laser for treatment of a periapical abscess which developed after conventional endodontic obturation. The laser performed the soft tissue incision, osteotomy, and root resection. The laser also contoured and prepared the osseous area for guided bone regeneration.

4. Dr. George Romanos uses a carbon dioxide laser to excise hypertrophic tuberosity soft tissue to achieve improved physiologic contour before placement of a new maxillary denture.

These cases show various clinical applications of three individual wavelengths and demonstrate how those lasers, in their specific tissue interactions, can be effectively used for successful treatment outcomes.
**SYNOPSIS**

An Er:YAG laser was used without anesthesia for removal of carious lesions in two anterior teeth, and then composite resin restorations were placed.

**PRETREATMENT**

**A. Outline of Case**

1. Full Clinical Description

A 58-year-old male patient presented to the office for the specific purpose of “having his broken front teeth fixed” (Figure 1). The patient's medical history was free of any ailments or conditions that needed to be addressed prior to treatment. He had been seen previously in the office for the purpose of a comprehensive examination and treatment plan. The patient proceeded with only some of the recommended treatment. Intraorally, the majority of his posterior dentition was missing and the remaining teeth exhibited generalized gingival recession as well as periodontal disease. He was in Class I occlusion and exhibited normal mandibular range of motion.

2. Radiographic Examination

A panoramic radiograph revealed several missing teeth as well as advanced generalized bone loss in both arches. Otherwise, no visible abnormalities, significant radiolucencies or radiopacities were present in the maxilla or the mandible. A periapical radiograph revealed caries in teeth #7 and 8 on the distal aspect of the root surface (Figure 2).

3. Soft Tissue Status

Prior to treatment, oral cancer and periodontal examinations were performed. The probing chart is shown in Figure 3 and the patient was diagnosed with moderate-to-severe periodontitis and was undergoing therapy for this condition. Previously, he had received scaling and root planing which reduced bleeding and inflammation. The buccal mucosa, sublingual areas, and palate exhibited no signs of any suspicious lesions; tissue exhibited no hyperkeratosis which can often appear on the tissue of cigarette-smoking patients.

4. Hard Tissue Status

As shown in Figure 4, in the maxilla, only the anterior teeth
were present; three molars were missing in the mandible. Due to the patient’s periodontal status, the ridge level was less than desirable. Also, bone loss around the remaining teeth was no less than 30% resorbed at its greatest height. Teeth #7 and 8 exhibited decay as well as staining from smoking. The teeth tested vital.

5. Other Tests
Blood pressure levels were within normal ranges. Occlusal evaluation demonstrated mandibular range of motion within normal limits.

B. Diagnosis and Treatment Plan
1. Provisional Diagnosis
A mesial incisal fracture of tooth #7.

2. Final Diagnosis
Extensive caries close to the pulp on both teeth #7 and 8. Tooth #7 had significant loss of incisal edge structure and there was extensive root surface caries on the distal of tooth #8. Both teeth may require endodontic therapy after caries removal.

3. Treatment Plan Outline
The primary objective was to restore teeth #7 and 8 using an Er:YAG laser in the following sequence:

a. Remove all decayed tooth structure
b. Decontaminate bacteria in areas of tooth preparation close to the dental pulp
c. Refine composite preparation by shaping, etching, and beveling the enamel
d. Restore cavity with hybrid composite resin, and then evaluate both the pulpal status and the necessity for crown restorations.

4. Indications
Caries removal is necessary for the tooth restoration, and the Er:YAG laser can easily remove the diseased structure. This laser wavelength is more readily absorbed by tissue with a higher water content such as a carious lesion; therefore it is possible to more easily conserve healthy tooth structure. In addition, the relative lack of tactile stimulation offered by laser treatment compared to conventional high-speed handpieces often allows the procedure to be performed without the need for needle analgesia.

5. Contraindications
There are no absolute contraindications for performing the procedure, except that the time required for the laser to accomplish caries removal and tooth preparation can be longer than when a high-speed handpiece is used.

6. Precautions
Adequate water spray must be maintained as caries are being removed. Since the erbium laser preferentially interacts with diseased tooth structure, good visibility and low power will be necessary for careful preparation in order to avoid both thermal damage and excessive removal of tooth structure.

7. Treatment Alternatives
Alternatives to treatment methods include the use of injected anesthetics and conventional handpiece with burs for cavity preparation and preparation refinement.

8. Informed Consent
Upon receiving a full explanation of the procedure, with associated risks, benefits, and alternatives, the patient gave verbal consent to perform the treatment.

TREATMENT
A. Treatment Objectives
Strategy
The primary objective was to perform the majority of the caries removal, cavity preparation, enamel etching, and beveling utilizing the Er:YAG laser comfortably and efficiently without the use of injectable dental anesthetics.

B. Laser Operating Parameters
The Er:YAG laser (DELight, HOYA ConBio, Fremont, Calif.) with a wavelength of 2940 nm was used with its fiber delivery system and a 600-micron quartz tip. It operates in a free-running pulse mode with a pulse duration of 300 msec. The laser was used at 30 Hz, 180 mJ, 5.4 W, and also at 30 Hz, 70 mJ, 2.1 W, both with water spray, during the procedure. The tip was used in both contact and noncontact (defocused) modes.

C. Treatment Delivery Sequence
Prior to commencing the procedure, the patient was familiarized...
with the procedural steps. Subsequently, all laser safety precautions were performed. These included but were not limited to the administering of laser safety glasses to the patient and operators, displaying laser hazard signage, and inspecting the mechanical aspects of the laser. Once safety systems were in place, the laser was test-fired to insure proper beam function and water spray delivery. The laser pulse rate was set to 30 Hz and the laser energy was set to 180 mJ which produced a power of 5.4 W. As the target tissue was addressed, high-volume suction was used continuously. The laser beam was defocused approximately 2 cm from the target tissue for 90 seconds (Figure 5). The beam was directed closer to the decay with a brushing-like motion until ablation began. The tip was kept in a close noncontact position as the decay was removed until the preparation depth extended close to the pulp. The energy was then lowered to 70 mJ (2.1 W of power) for further caries removal and bacterial decontamination. After the caries were removed, the settings were returned to 30 Hz/180 mJ for the purpose of beveling and “laser-etching” the enamel (Figure 6). Clearfil SE Bond (Kuraray America, Inc., New York, N.Y.) was applied to enamel and dentin surfaces and a 0.4-micron filler

D. Postoperative Instructions
The patient was told that he could resume normal activities due to the lack of numbness as a result of no injections. The patient was told to call the office if pain or any other unusual symptoms occurred.

E. Complications
No complications occurred during or after the procedure.

F. Prognosis
The prognosis for the success of the procedure and restorations was good. The patient was informed that the lesions were close to the pulp and may require endodontic therapy. Due to the size of the lesion, it was recommended tooth #7 receive a crown in the future.

G. Treatment Records
Treatment records, including the details outlined above, were included in the patient’s chart notations.

FOLLOW-UP CARE
A. Assessment of Treatment Outcome
The objectives originally set were achieved. The entire procedure was performed with success without the use of dental anesthetic. In addition, satisfactory esthetic results were obtained.

B. Complications
At 6 months, an incisal fracture was observed on tooth #8 (Figure 8). The patient stated that the fracture was the result of a mop handle hitting him in the mouth. The incident did not affect the integrity of the restoration or the vitality of the tooth.

C. Long-Term Results
At the 6-month postoperative visit, the integrity of the restoration and vitality of the teeth restored were evaluated. The patient stated that he had experienced no problems with either restoration. Both teeth maintained healthy vitality tests and the surfaces were sealed (Figure 8). Periodontally, the gingiva exhibited slight inflammation that can be resolved with a periodontal maintenance procedure. The incisal edge of tooth #8 was repaired using the laser and composite, and the patient was instructed to improve his oral hygiene (Figure 9). The radiograph
at 6 months showed healthy periapical tissues (Figure 10).

D. Long-Term Prognosis
Although the restorations of the treated teeth show good integrity and function, the long-term prognosis is dependent upon proper periodontal maintenance, replacement of posterior teeth, and the patient’s oral lifestyle.

AUTHOR BIOGRAPHY
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Disclosure: Dr. Wyatt has no financial connections with or interests in any dental companies.
The Use of an Er:YAG Laser (2940 nm) in Soft and Hard Tissue Surgery for Esthetic Enhancements

Raminta Mastis, DDS, St. Clair Shores, Michigan

SYNOPSIS

The use of an Er:YAG laser for esthetic crown lengthening is reported. This wavelength can be used for removing and recontouring both the gingiva and the underlying osseous structures to achieve the desired new tooth proportions prior to restoration.

PRETREATMENT

A. Outline of Case

1. Full Clinical Description

A 44-year-old male patient presented for a cosmetic consultation for improving his smile. He was seeking a third opinion because his own dentist and a second opinion offered him very differing treatment plans and he was confused. The patient stated that he was recently divorced and also quit smoking and now wants to do something about his teeth. He did not like the appearance of his teeth because they were “short and stained.” He also had spaces between his teeth that he did not like.

The consultation addressed esthetic principles. Clinical examination revealed severe incisal attrition of both maxillary and mandibular anterior teeth. The patient had at least a 1.0-mm diastema between the maxillary central incisors (with evidence of bonding attempts to minimize space), with a low labial frenum insertion just above the teeth (Figures 1-3). There was no evidence of caries or of additional fracture; however, several posterior teeth exhibited some evidence of cervical abfractions. Additionally, the patient had occlusal wear facets on posterior teeth, which confirmed parafunction such as bruxism. Both TMJs appeared normal to palpation and movement.

The patient’s medical history included recently quitting smoking. The patient was taking Lipitor® for his cholesterol levels and had an allergy to codeine. The patient had no medical concerns or contraindications for treatment.

Dental history included multiple posterior teeth restored with moderate-size fillings. Several molars (#1, 14, 18, and 30) were removed in the military more than 20 years ago. The patient had a natural dentition with a Class I occlusion and had maintained...
regular recall appointments.

2. Radiographic Examination
Both periapical and panoramic radiographs of the maxillary teeth showed no evidence of osseous or periapical pathologies (Figures 4-5). There was no significant bone loss surrounding any of the maxillary anterior teeth, which would be typically associated with periodontal disease. Teeth #1, 14, 18, and 30 were missing, resulting in some mesial tipping of remaining molars. There were moderate-size restorations on posterior teeth as well as a large composite on tooth #9, with no evidence of uncontrolled caries.

3. Soft Tissue Status
The patient had generalized healthy periodontium. The periodontal probing was 1-3 mm throughout the maxillary anterior region with no bleeding. The anterior teeth were surrounded with a broad band (9-14 mm width) of attached gingiva with stippling. The tissue was pink, firm, and healthy. Periodontal probing of the posteriors ranged from 2-5 mm. Some of the deeper probing was associated with the mesial tipping of molars after neighboring tooth loss. The tongue, floor of mouth, palate, cheeks, and lips were all within normal limits.

4. Hard Tissue Status
Examination of dental hard tissue revealed the following of note: Tooth #9 had a large bonded restoration, and was slightly shorter than #8 (resulting from trauma to tooth #9 more than 20 years ago). Several posterior teeth had moderate-size restorations which appeared in satisfactory condition. The maxillary laterals exhibited rotation. Spacing was evident in the posterior region from drifting into areas of molar extraction sites (Figure 6). The patient had evidence of bruxism (or similar parafunction) due to the wear patterns on occlusal surfaces. Despite this, his temporomandibular joints were asymptomatic.

5. Other Tests
A diagnostic cosmetic mock-up was made as a guide for visualizing the restorative plan as well as for measurement purposes for the proposed crown lengthening procedures. Additionally, bone sounding (with local anesthetic) was performed prior to surgery to evaluate bone levels for maintaining biologic width.

B. Diagnosis and Treatment Plan
1. Provisional Diagnosis
Healthy periodontium with shortened teeth due to excessive incisal wear.

2. Final Diagnosis
A final diagnosis was made of healthy periodontal tissues with esthetically compromised maxillary anterior teeth, where the gingiva had encroached onto the enamel in the cervical areas. In addition, a low attachment of the maxillary labial frenum with an insertion point just above the central incisors contributed to the diastema as well as to limiting lip retraction and was at a height which compromised a full smile.

3. Treatment Plan Outline
It was decided to perform a full gingivectomy at the upper anterior segment, employing an associated flap procedure and labial frenectomy. In this way, the mobility of the upper lip would be improved and a more pleasing esthetic appearance of the anterior teeth obtained. The objective was to reduce the gingiva by 2 to 3 mm, with osseous recontouring to maintain the biologic width. All treatment would involve the use of an erbium:YAG laser. Following a healing phase, the final restorative plan would include the provision of esthetic porcelain restorations.

4. Treatment Plan Alternatives
Alternatives to laser use:
- The use of traditional surgical procedures including scalpel for the incision and raising the flap, followed by rotary instrument for osseous recontouring. The use of scalpel or electrosurgery for the labial frenectomy and gingivectomy.
- Since the proposed treatment was elective to aid in improving the esthetic result, an alternative included refraining from surgery altogether and accepting compromises in restorative attempts.

5. Indications for Laser
The use of an Er:YAG laser is considered ideal for this type of hard and soft tissue surgical procedure because the same instrument can be used to perform the various stages of treatment. Laser osseous contouring offers improved visualization of the surgical site because of the small laser operating tip, as opposed to restrictions of visualization with the head of a rotary handpiece. Additionally, the laser is an asset for efficient osseous ablation due to minimal trauma to vital tissue, as opposed to rotary instrumentation, and has an advantage for clearing debris from the surgical site rather than creating a smear layer on freshly cut bone by a rotary handpiece. Anecdotally, the laser may result in less postoperative discomfort.

Figure 6: Preoperative maxillary occlusal view
6. Contraindications for Laser
There were no absolute contraindications for the use of the laser on this patient. Proper energy control needs to be adjusted for the tissues treated both to avoid tissue overheating and also to prevent collateral thermal damage to adjacent tissue structures. Care must be taken to avoid an air embolism in a flapped surgical site by directing the air away from the attachment.

7. Precautions
The Er:YAG laser wavelength easily interacts with both hard and soft tissue, so care must be taken to avoid interaction with any associated healthy tissue, especially hard dental tissue. It is important that adequate water spray be used during soft tissue ablation to avoid thermal damage through charring.

8. Informed Consent
The patient was well informed about the treatment proposal and the benefits and risks involved. The patient was also given the option to have the surgical procedures performed by a periodontist. Written and verbal consent were obtained from the patient for the surgical procedures as well as use of the photographs.

TREATMENT
A. Treatment Objectives

The Er:YAG (2940 nm) laser would be used to carry out the following stages of treatment:
• Ablate the fibrous tissue of the maxillary frenum
• First probe pocket depths (Figure 7), mark and outline the proposed gingivectomy (Figure 8), then incise the soft tissue, following this outline to remove gingival tissue for the gingivectomy procedure
• Assist in raising a full thickness flap for access to the surgical site
• Contour the crestal bone adjacent to the anterior teeth to a minimum measurement of 3.0 mm below the height of the gingiva for establishment of a healthy dentogingival complex.

Following surgical correction, the flap would be sutured and allowed to heal.

B. Laser Operating Parameters
A 2940-nm wavelength free-running pulsed Er:YAG laser (HOYA ConBio, Fremont, Calif.) was used. The energy was delivered through an optical zirconium aluminum fluoride fiber to a 600-micron quartz tip with an 80-degree curve.

The frenectomy was performed with settings of 20 Hz repetition rate and 70 mJ per pulse, with water, for approximately 30 seconds total. For the gingival outlining, a setting of 10 Hz repetition rate and 35 mJ per pulse, without water, was used. For the gingivectomy, water was added and the surgical settings were increased to 20 Hz repetition rate and 70 mJ per pulse, for a total of 30 seconds per tooth. The tip was kept in noncontact mode (about 0.5 mm away from the tissue surface). The incision for the flap was continued at the same settings as for the gingivectomy, with water. For the osseous recontouring, the same setting of 20 Hz and 70 mJ was used with water for a total of about 40 seconds per tooth in a combination of noncontact and light-contact mode. The average power for the soft and hard tissue procedures was 1.4 Watts.

C. Treatment Delivery Sequence
All safety precautions, which included laser protective eyewear for the patient, doctor and assistant, were verified by the laser safety officer. The laser was test-fired into water, using minimum operating parameters, to establish correct function and patency of the delivery system. Local anesthetic was administered with buccal infiltration and allowed to take effect.

The laser was set to the soft tissue settings and test-fired outside the mouth. The upper lip was retracted to maintain tension on the frenum. The laser was fired (with water) at the fibrous attachment in order to facilitate release and then used to ablate fibrous connective tissue at the site of frenum insertion on the alveolus. The laser was used in noncontact and light-contact mode. No sign of charring was observed (Figure 9). No sutures were required.

The laser settings were reduced, the tip was examined and the laser
was test-fired outside the mouth. The laser was then used without water to mark reference spots (Figure 10) and to outline the gingival contours of the proposed gingivectomy as an aid to determine how much tissue would be removed or contoured for the desired cosmetic result (using the diagnostic mock-up as a guide). The laser settings were reset to the soft tissue surgical settings and test-fired again outside the mouth. The gingivectomy excision was performed (Figure 11) using a noncontact mode first on the right side on teeth #6, 7, and 8, then repeated on the left side on teeth #9, 10, and 11. Water was used to aid in cooling neighboring tissue and underlying bone and thus reduce collateral thermal injury. No sign of charring was observed (Figure 12).

The level of the alveolar crest on the facial surface of each of the anterior teeth was again verified with bone sounding and confirmed to be deficient for maintaining a healthy dentogingival complex. The laser tip was examined, cleaned, and test-fired outside the mouth. A vertical releasing incision was made (with water, noncontact mode) on the distal aspect of the interdental papilla between teeth #5 and 6. The laser was used in contact mode to aid in the release of the attached gingiva by directing the tip (with water and soft tissue settings) in the pocket parallel to the surface of the tooth. A periosteal elevator was used to reflect the full thickness flap on the right side from tooth #6 to #8. The osseous tissue was contoured with the laser in short intervals, utilizing noncontact mode with water. Care was taken to keep the tip parallel to the root surface (Figure 13) to avoid removing cementum or ablating the root surfaces of the vital teeth. Also care was taken to aim the water/air spray away from the soft tissue flap to avoid an air embolism. High-speed suction was used throughout the procedure for the purpose of cooling, removing plume, and evacuating debris and water to allow proper visualization of the postoperative surgical site (Figure 14). The procedure was repeated on the left side (Figure 15) with the vertical releasing incision on the distal aspect of the interdental papilla between teeth #11 and 12, and a full thickness flap raised from tooth #11 to the midline for osseous recontouring. The same settings and procedure used on the right side were repeated on the left. The flap was repositioned over the maxillary anteriors (Figure 16), sutured into place (Figure 17), and allowed to heal.

D. Postoperative Instructions
The patient was instructed to minimize disturbance of the sutured area, but to begin gentle warm salt water rinses the following day. The patient was also instructed to pull up on his upper lip once per hour during waking hours for several days and to keep site clean. He was instructed to maintain oral hygiene of the rest of his teeth. A prescription for Motrin® 800 mg was written to relieve pain, if any. The
The patient was advised to call the office immediately if he noted any adverse reactions or problems.

**E. Complications – Types, Events, Management**

After the completion of the surgical procedures, a hematoma was noted in the maxillary right vestibule near the site of the frenectomy. This was associated with the manipulation of the lips for retraction during the appointment. Management included watching the area at postoperative appointments, with no specific intervention at this time. The patient was contacted the following day and he reported no discomfort and had no need to use any analgesics. The patient was seen two days later for evaluation, and the area was healing uneventfully with no postoperative discomfort. One week after the surgery, the sutures were removed. The hematoma in the maxillary labial vestibule was resolving uneventfully. The healing of the surgical sites was progressing satisfactorily and the patient was comfortable throughout the period.

**F. Prognosis**

There were no significant complications arising from the procedures, and the long-term prognosis for the gingival healing from the crown lengthening procedure as well as the frenectomy was excellent.

**G. Treatment Records**

All treatment data, including the type of laser used, operating parameters, materials used, intraoral photos and radiographs, were recorded along with the written documentation.

**FOLLOW-UP CARE**

**A. Assessment of Treatment Outcome**

The patient was instructed to resume normal oral hygiene home care. At the two-week postoperative visit, the gingival tissue was pink and adhering to underlying bone with no evidence of inflammation. The patient had no complaints of discomfort and was happy with the elongation of his teeth.

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He was contacted the next day after surgery. He reported no discomfort and was not taking any analgesics. At the one-week follow-up, the sutures were removed, the tissue looked pink, the incisions were healing satisfactorily (Figures 20-21), and the patient had no complaints. At the second-week follow-up, the tissue continued to heal satisfactorily with no evidence of swelling or inflammation (Figure 22). At the one-month follow-up, the frenum had healed in a more superior position. The tissue surrounding the teeth looked pink and firm, and the tissue height remained stable (Figure 23). The patient was happy with his longer teeth, but was now
concerned about the color and staining from years of smoking. Impressions were made for take-home bleaching trays and delivered together with a 30% carbamide peroxide gel (Life-Like Cosmetic Solutions, Harbor Dental Bleaching Group, Inc., Santa Barbara, Calif.) and instructions. Periodontal probing were performed at the three-month follow-up and confirmed good gingival health and reestablishment of a healthy dentogingival complex; sufficient biologic width to proceed with esthetic restorative procedures was noted (Figures 24-27). An average of 2.0 to 3.0 mm of crown length was gained through the surgical procedures, and thus the treatment objectives were met.

B. Complications
Aside from the self-resolving hematoma in the labial vestibule, no complications were noted and the patient was comfortable throughout the healing period.

C. Long-Term Results and Prognosis
The long-term outlook for the frenectomy and crown lengthening procedures is considered excellent. The patient now has good bony support for the crown-lengthened teeth, and has good gingival architecture with adequate attached keratinized gingiva. A healthy dentogingival complex had been established and prepared for the esthetic restorative procedures. The area is healthy, stable, and maintainable for the patient with normal oral hygiene home care. The patient is happy with the results and is motivated to refocus his financial concerns to proceed with the proposed esthetic restorative phase of the treatment plan.

AUTHOR BIOGRAPHY
Dr. Raminta Mastis received her dental degree from the University of Illinois College of Dentistry in 1987. She maintains a private practice in St. Clair Shores, Michigan, focusing on integrating cutting-edge technology in general dentistry. She is a member of the Academy of Laser Dentistry and has Standard Proficiency certification in Er:YAG, Er:Cr:YSGG, diode, and CO₂ laser wavelengths. In 2006 she achieved Advanced Proficiency in the Er:YAG laser wavelength. Dr. Mastis may be reached via e-mail: mastis@bignet.net.

Disclosure: Dr. Mastis has no commercial relationships relative to this case study.
CLINICAL CASE

Periapical Surgery and Guided Tissue Regeneration with an Er:YAG Laser
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SYNOPSIS
Successful use of an Er:YAG laser is reported for treatment of a periapical abscess which developed after conventional endodontic obturation. The laser performed the soft tissue incision, osteotomy, and root resection. The laser also contoured and prepared the osseous area for guided bone regeneration.

PRETREATMENT
A. Outline of Case
1. Clinical Examination
A 52-year-old female patient presented pain to percussion and a buccal abscess on tooth #19 (Figure 1). She did not present with any alterations of the TMJ or abnormalities in the soft tissues, but exhibited poor oral hygiene. Occlusion was Angle’s classification Class I. The patient’s medical history revealed no significant medical history or predisposing risk factors.

2. Radiographic Examination
Intraoral and panoramic X-rays (Figures 2 and 3) showed the origin of the abscess, a periradicular radiolucency associated with the distal root apex of tooth #19. A gutta-percha indicator point was inserted for clarity (Figure 4); it marked an endodontic periapical abscess mimicking a deep periodontal pocket. The fistula drained into the sulcus.

3. Soft Tissue Status
There was buccal gingival inflammation adjacent to tooth #19, and the periodontal probe reached a depth of 12 mm (Figure 5). All other pockets probed less than or equal to 3 mm. Except for the facial aspect of tooth #19, all other soft tissues presented a normal appearance.

4. Hard Tissue Status
Tooth #19 was nonvital, having been previously endodontically treated. Teeth #15 and #30 were missing; there were no carious lesions present, and the three existing amalgam restorations were intact. The osseous structures appeared normal.

5. Other Tests
The test to percussion was positive on tooth #19 and the occlusion of the porcelain-fused-to-metal (PFM) crown was greatly reduced in order to alleviate the chewing pain.

B. Diagnosis and Treatment Plan
1. Provisional Diagnosis
Draining fistula of endodontic origin.

Figure 1: Initial view of the buccal fistula on tooth #19. The crown had just been removed

Figure 2: Preoperative panoramic film

Figure 3: Preoperative periapical film showing radiolucency at the apex of the distal root of tooth #19

Figure 4: Preoperative film of a gutta-percha point that was placed into the fistula, extending toward the periapical area

Figure 5: Preoperative view of periodontal probing of a 12-mm buccal pocket
2. Final Diagnosis
Endodontic periapical abscess originated by the failure of the distal root endodontic treatment of tooth #19.

3. Treatment Plan Outline
Periapical surgery of the distal root of tooth #19 with the use of an Er:YAG laser, and the guided tissue regeneration of the bone defect.

4. Indications
Treatment is necessary to remove the infectious process and restore the periodontal support of the tooth.

The Er:YAG laser is indicated for the treatment due to the fact that this wavelength (2940 nm) is very well absorbed by the water of the gingiva and by the water and the mineral of the dental and osseous tissues.

5. Contraindications
No contraindications were considered for laser treatment.

6. Precautions
Adequate water cooling must be used during osseous surgery and the air component of the spray must be minimized to avoid the possibility of an air embolism in the soft tissue flap.

7. Treatment Alternatives
Treatment alternatives included endodontic retreatment and periapical surgery with conventional instruments, or the extraction of the tooth and a prosthodontic procedure.

8. Informed Consent
The risks and benefits of treatment were explained. Verbal consent was obtained from the patient.

TREATMENT

A. Treatment Objectives

Strategy
Use of an Er:YAG laser to perform osteotomy and root resection without vibration or discomfort, and to provide bacterial reduction of the bone cavity, less contamination of the surgical site, and better healing and postoperative course.

B. Laser Operating Parameters
- Er:YAG laser used: Opus Duo E (Opusdent, Yokneam, Israel)
- Wavelength: 2940 nm
- Delivery system: Hollow waveguide with angulated handpiece
- Emission mode: Free-running pulsed
- Spot size: 400 µm in soft tissue, 800 µm on dental tissue, and 1300 µm in bone tissue
- Energy per pulse: 250 mJ (soft tissue) and 500 mJ (hard tissue)
- Hertz: 20 pulses per second (in soft tissue) and 12 pulses per second (in hard tissue and in granulation tissue)
- Power ranging from 3 to 6 W
- Water cooling used for all procedures
- Total time: 19 minutes of laser energy exposure.

C. Treatment Delivery Sequence
The safety measurements were established: a test-fire of the laser was performed to establish correct working and patency of the waveguide delivery system. A safety area check (only required personnel present, safety warning signs posted, and minimal reflective surfaces) was carried out. The patient and all personnel within the above-mentioned safety area were issued protective glasses.

High-volume evacuation was used for tissue cooling and suction of removed tissue.

Local anesthesia of 2% lidocaine HCl with epinephrine at 1:100,000 was administered. With an initial average power of 5 Watts (250 mJ, 20 pps), an intrasulcular laser incision was performed using a 400-µm HPX™ Conical Sapphire Tip with light brush strokes (contact mode) (Figure 6). The flap was elevated with hand instruments. There was an 8-mm probing depth osseous defect (Figure 7). The osteotomy was performed using an average power of 6 Watts (500 mJ, 12 pps) (noncontact mode), and the laser tip (1300-µm Sapphire Noncontact Tip™) was focused 2 to 3 mm away from the bone surface (Figure 8). The granulation tissue was
removed with hand instruments and lased with an average power of 3 Watts (250 mJ, 12 pps) (1300-µm Sapphire Noncontact Tip™) (noncontact mode) (Figure 9). The root apex was excised (Figure 10) and the remaining root area was disinfected using an average power of 6 Watts (500 mJ, 12 pps). The laser tip (800-µm HPX™ Conical Sapphire Tip) was again focused 2 to 3 mm away from the root surface, avoiding contact with the post. No retrofilling material was used (Figure 11). Natural bone mineral of bovine origin (Bio-Oss®, Osteohealth, Shirley, N.Y.) (Figure 12) and a collagen membrane (Bio-Gide®, Osteohealth) were used for the guided tissue regeneration. Flaps were sutured in place with 4-0 silk sutures (Figure 13). A postoperative intraoral X-ray was taken (Figure 14).

D. Postoperative Instructions
The patient was instructed to stay on a soft diet, and she was prescribed 0.12% chlorhexidine gluconate mouthrinse, amoxicillin 500 mg every 8 hours for 7 days to avoid infection, and ibuprofen 600 mg every 8 hours if she had pain. She was told to return for a follow-up appointment in two weeks.

E. Immediate Complications
There were no complications during or after treatment and no side effects were noted.

F. Prognosis
All objectives of treatment were met and the prognosis was considered excellent.

G. Treatment Record
All the information of the treatment was stored in the clinical record of the patient.
CLINICAL CASE

FOLLOW-UP CARE

A. Assessment of Treatment Outcome

Follow-up assessment was carried out at two weeks (Figure 15), one month (Figures 16 and 17), four months, and one year. At four months, the radiograph showed good healing (Figure 18) with the probing depth decreased to 4 mm, although healing was still taking place (Figure 19). The PFM crown was replaced at four months (Figure 20).

B. Complications

There were no side effects or complications.

C. Long-Term Results

Excellent healing of the soft and bone tissues was observed at one year, both radiographically (Figure 21) and clinically, with the pocket reduce to 2 mm (Figure 22).

AUTHOR BIOGRAPHY

Dr. Alberto Trigas received his dental degree from the Faculty of Medicine and Dentistry, University of Santiago de Compostela, Spain. He is a practicing general dentist in Carballino, Ourense, Spain. Dr. Trigas is a member of the Spanish Society of Oral Surgery (SECIB), the Spanish Society of Periodontology and Osseointegration (SEPA), the European Federation of Periodontology (EFP), the Spanish Society of Lasers in Dentistry (SELO), the European Society for Oral Laser Applications (ESOLA), and the Academy of Laser Dentistry (ALD). He has completed his Advanced Proficiency in the Er:YAG laser wavelength. Dr. Trigas can be reached by e-mail at clinicatrigas@ya.com.

Disclosure: Dr. Trigas has no financial relationship with any dental laser manufacturer.
The Use of a CO$_2$ Laser in the Reduction of Maxillary Tuberosity

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SYNOPSIS

This case report describes the successful use of a carbon dioxide laser to excise hypertrophic tuberosity soft tissue to achieve improved physiologic contour before placement of a new maxillary denture.

PRETREATMENT

A. Outline of Case

1. Full Clinical Description

A 43-year-old white male patient presented for consultation as a referral. His medical history was uneventful. His prime dental complaint was the presence of enlarged bilateral maxillary tuberosities, which hindered the comfortable wearing of a full upper denture. Clinical examination confirmed the presence of large fibrous overgrowths in the left and right tuberosity region of the maxilla. He was edentulous and had worn upper and lower full dentures for many years, with some difficulty.

2. Radiographic Examination

The pretreatment Panorex radiograph showed no remaining roots in the jaws, no cystic lesions, or other findings of pathology. The maxillary sinuses were slightly enlarged, but did not account for the increase in size of the tuberosities.

3. Soft Tissue

Two soft tissue tumors were found from the tuberosities over the alveolar ridges at the left and right side of the maxillary ridge. The depth of the vestibulum on both sides was normal. The soft tissue was not inflamed and not irritated. The color and consistency was normal, without any hardness. Each tuberosity was covered by keratinized tissue. All other oral soft tissues were normal.

4. Hard Tissue Tests

No hard tissue tests were performed.

5. Other Tests

With the full upper denture in place, the occlusion was normal, both in centric and excursive movements. TMJ function appeared normal.

B. Diagnosis and Treatment Plan

1. Provisional Diagnosis

A provisional diagnosis was made of symmetrical soft tissue tumors at the left and right side of the maxilla over the alveolar ridge (Figure 1).

2. Final Diagnosis

Palpation of the fibrous masses indicated a bilateral fibrous overgrowth of keratinous postextraction gingival tissue, consistent with phased extractions and an ill-fitting upper denture. Following all investigations, a final diagnosis was made, which formed the basis for corrective treatment.

3. Treatment Plan Outline

The enlargement of both maxillary tuberosities had made the fitting and comfort of the denture difficult. It was considered that treatment should be offered to excise the hypertrophic tuberosity tissue, in the regions of teeth #1-5 and #11-16 using a CO$_2$ laser, and to redefine an acceptable, stable soft tissue profile prior to provision of a new maxillary full denture. It was considered that postoperative and future management depended on the outcome of surgical treatment.

4. Indications for Treatment

The CO$_2$ laser wavelength is characterized by a surface ablation of tissue containing water. Consequently, this would allow soft tissue excision and ablation, using a dissecting technique, with the benefit of hemostasis and obviation of soft tissue dressings. Careful use of the laser would prevent unwanted thermal damage to the underlying tissues. Removal of the tumors would be advised in order to control continuous tumor growth and in order to establish a good prosthetic environment for the base of a new full denture.

5. Contraindications for Treatment

This case report describes the successful use of a carbon dioxide laser to excise hypertrophic tuberosity soft tissue to achieve improved physiologic contour before placement of a new maxillary denture.

Figure 1: Preoperative appearance showing bilateral hypertrophy of maxillary tuberosity region
Standard Treatment: Whenever tumor removal in the palate is involved, attention must be given to the anatomical limitations such as the lesser palatine artery in this area, in order to control spontaneous bleeding. The full denture would need to be relined immediately after surgery to reduce swelling and control bleeding.

Laser Treatment: The CO\textsubscript{2} laser wavelength easily interacts with the soft tissues, without high penetration depth. Care must be exercised to use suitable laser power, in order to prevent the build-up of char and also to remove any char at frequent intervals.

6. Precautions There is a need to recognize the limitations of both continuous wave and (gated) chopped emission modes, in relation to the thermal relaxation potential for target tissue. The potential for conductive heat transfer during laser use may be high, where the soft tissue is thin and underlying alveolar bone is exposed to such transfer. The use of possible precooling of tissue and damp gauze to remove charred tissue remnants at frequent intervals during treatment must be considered.

7. Treatment Alternatives Alternatives to be considered include:
- Conventional soft tissue surgical excision, using a scalpel, under local anesthesia
- Similar excision using another type of laser wavelength.

8. Informed Consent The need, benefits, and risks of the procedure were outlined and verbal consent was obtained from the patient. These were recorded in the treatment notes.

TREATMENT

A. Treatment Objectives
Strategy
Use of a CO\textsubscript{2} laser (10,600 nm wavelength) for tumor excision as well as ablation and coagulation. Strategic factors include the use of suitable power levels to cut fibrous tissue without causing collateral damage, the employment of a dissection technique, placing tissue to be excised under tension to aid in the surgical excision.

B. Laser Operating Parameters
The laser operating parameters used were as follows:
- Laser: CO\textsubscript{2} laser (SC 30, Weil Dental, Rosbach, Germany)
- Wavelength: 10,600 nanometers
- Delivery System: Articulated arm. Handpiece with a ceramic tip of 0.8-mm diameter with adjustable air spray
- Power: 0.1 to 10.0 Watts
- Repetition rate (gated [super-pulsed] emission mode): 0.1 to 3 kHz; pulse length: 140 µsec
- Laser Settings: Initial incisions: Focused, noncontact super-pulse mode and a control panel power setting of 8 Watts (continuous wave); distance from the tissue 2 mm
- Ablation of the tissue: Defocused beam with a distance from the tissue more than 2 mm. Time taken, per tissue site: 2 min.

C. Treatment Delivery Sequence
Prior to patient treatment, the operating room was secured and proper laser warning signs placed. The laser was set up and test-fired, using minimum operating parameters, to ensure proper function and patency of the delivery system. Supplies were dispensed and equipment and sterile instruments arranged for treatment. The patient was seated, the treatment plan reviewed, and consent affirmed. Correct safety eye protection was provided for both patient and operating personnel.

Local anesthesia (lidocaine 2%, epinephrine 1:80,000) was administered buccally and palatally at each tumor site.

Figure 2: Surgical excision of excess tissue. The tissue is held under traction to assist laser cutting. Care is taken to keep the zone of the excision above the level of the periosteum

Figure 3: Treatment sites immediately after laser excision

Laser Procedures: A focused beam of the CO\textsubscript{2} laser was used to perform an excision at the base of each tuberosity in turn, taking care to remain above the periosteum. Laser energy was delivered to separate the excess tissue, using a focused, noncontact mode and a power setting of 8 Watts (continuous wave) at a distance from the tissue of 2 mm, with a ceramic tip of 0.8-mm diameter. The handpiece was kept parallel to the base of the tumor in order to cut efficiently and to avoid penetration in the deeper areas (Figure 2). A significant coagulation was performed using the CO\textsubscript{2} laser in order to help prevent spontaneous bleeding and postoperative infection (Figure 3).

The excised tumor was sent for histological examination with a note indicating tissue removal was accomplished via laser. Immediately after laser surgery, the upper denture was relined with a self-polymerizing base and fitted.
D. Postoperative Instructions
The patient was instructed to continue home care, and mouth rinsing with Listerine® twice daily was recommended. No limitations were considered necessary on eating or drinking. The patient was advised to call if any problems were to occur. The patient was reappointed for one-week and one-month recall visits.

E. Management of Complications
The patient was advised of the likely outcome of surgery in terms of initial soreness. No other complications were reported.

F. Prognosis
Following the correct use of the laser in this procedure in achieving the desired outcome, it was believed that the prognosis for success was good.

G. Written Notes
The details of treatment provided, laser operating parameters, and clinical outcome were recorded in the patient’s notes.

FOLLOW-UP CARE
A. Assessment of treatment:
The patient was assessed at one week, one month, and six months. At the one-week appointment, no problems were noted and wound healing was uneventful. Fibrin tissue covered the whole wound area. At the edges of the laser wound new capillaries were observed giving the appearance of regeneration of a new, healthy tissue. No irritation or inflammatory reaction was found. At one month, no irritations or inflammatory reaction were found and no evidence of scar tissue formation was observed. At this time the patient was referred to the Department of Prosthodontics for the fabrication of a new denture. The final result of the histological examination showed that the tumors were fibromas without any kind of malignancy.

B. Complications
No complications occurred in the management of this case.

C. Long-Term Results
Considerable excess tissue had been removed during this treatment. Through the care taken and the necessary changes to the fit surface relationship of the denture with the surgical sites, the tissue resolution had occurred in line with expectations.

D. Long-Term Prognosis
The long-term prognosis and the stability of the clinical result were considered good. Clinical recall examinations were advised during the six months following surgery, in order to control any possible recurrence. Six months after surgery the soft tissue was completely healthy (Figure 4).

AUTHOR BIOGRAPHY
Dr. George Romanos studied dentistry at the University of Athens, Greece. He moved to Germany to finalize his postgraduate studies in the areas of periodontics, prosthodontics, and oral surgery. He is fully trained in all of these specialties. He has been using lasers in dentistry for 14 years and is a board member of the Germany Society for Lasers in Dentistry (DGL) and the International Society for Lasers in Dentistry (ISLD). He is the author of more than 100 articles, the main author of a laser book in the field of oral surgery, and is on the editorial board of several peer-reviewed journals. He received his PhD at the University of Frankfurt, Germany. Since August 2004 he has been a Clinical Professor of Periodontology and Implant Dentistry in the New York University College of Dentistry, New York, where he also serves as Director of Laser Sciences. Dr. Romanos may be reached via e-mail: gr42@nyu.edu.

Disclosure: Dr. Romanos has no affiliation with any company relevant to this article.
Caries Removal and Composite Preparation for Primary Teeth

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SYNOPSIS
An Er:YAG laser was successfully used for removal of carious lesions in two molars in a child prior to placement of restorations.

PRETREATMENT
A. Outline of Case
1. Full Clinical Description
A 9-year-old girl presented to the office for restoration of her primary upper left molars (Figure 1). She had previously been seen for the purpose of examination and treatment planning. Her medical history exhibited no sign of any ailments or conditions that would contraindicate routine dental treatment. The patient was receiving early orthodontic therapy due to severe crowding in the incisor region. Her occlusion was classified as a skeletal and dental Class I. She had normal mandibular range of motion and exhibited excellent behavior in the chair.

2. Radiographic Examination
Panoramic and bitewing radiographs revealed crowded dentitions with caries present in teeth I and J. Otherwise, no visible lesions or abnormalities were present (Figures 2 and 3).

3. Soft Tissue Status
The crowding in the patient’s anterior segments had contributed to slightly inflamed interproximal papillae. Visual examination revealed no other sites with lesions, infection, or inflammation.

4. Hard Tissue Status
The patient exhibited maxillary and mandibular tooth/arch/size discrepancies. The crestal bone levels for a patient of her age were normal. Carious lesions had previously been restored and primary teeth had been extracted. No skeletal lesions or abnormalities were observed.

5. Other Tests
Due to the patient’s age, many other routine tests were not performed.

B. Diagnosis and Treatment Plan
1. Provisional Diagnosis
Distal-occlusal caries present in tooth I, mesial-occlusal caries present in tooth J.

2. Final Diagnosis
Both teeth had carious lesions that extended close to the pulp.

3. Treatment Plan Outline
The primary objective of treatment is to restore teeth I and J using an Er:YAG laser in the following manner:
   a. Remove all decayed tooth structure
   b. Decontaminate bacteria in areas of the tooth that may be close to the pulp.
   c. Restore carious lesions with light-cured composite resin
   d. Perform treatment without the use of needle anesthesia.

4. Indications
Caries removal is necessary for the tooth restoration, and the Er:YAG laser can easily remove the diseased structure. This laser wavelength is more readily absorbed by tissue with a higher water content such as a carious lesion; therefore it is possible to more easily conserve healthy tooth structure. Moreover, this wavelength does not appear to cause a pulpal temperature rise, and if pulp capping is necessary, there appears to be a good prognosis for a successful outcome. In addition, the relative lack
of tactile stimulation offered by laser treatment compared to conventional high-speed handpieces often allows the procedure to be performed without the need for needle analgesia.

5. Contraindications
There are no absolute contraindications for performing the procedure, except that the time required for the laser to accomplish caries removal and tooth preparation can be longer than when a high-speed handpiece is used.

6. Precautions
Adequate water spray must be maintained as caries are being removed. Since the erbium laser preferentially interacts with diseased tooth structure, good visibility and low power will be necessary for careful preparation in order to avoid both thermal damage and excessive removal of tooth structure.

7. Treatment Alternatives
Alternatives to treatment methods include the use of injected “caine” analgesics with high-speed handpiece for cavity preparation. Amalgam or composite material may be used for the restorations.

8. Informed Consent
Prior to the procedure, the patient’s mother was given a detailed explanation of how the laser would be used and she enthusiastically gave verbal informed consent.

TREATMENT
A. Treatment Objective Strategy
The primary objective is to perform the majority of the caries removal, cavity preparation, and preparation decontamination utilizing the Er:YAG laser comfortably and efficiently without the use of injectable anesthesia.

B. Laser Operating Parameters
The Er:YAG laser (DELight, HOYA ConBio, Fremont, Calif.) with a wavelength of 2940 nm was used with its fiber delivery system and a 600-micron quartz tip. It operates in a free-running pulse mode with a pulse duration of 300 msec. The laser was used at 30 Hz, 180 mJ, 5.4 W, and also at 30 Hz, 70 mJ, 2.1 W, both with water spray, during the procedure. The tip was used in both contact and noncontact (defocused) modes.

C. Treatment Delivery Sequence
Prior to commencing the procedure, the patient was familiarized with the intended treatment steps. Subsequently, all laser safety precautions were performed. These included but were not limited to the administering of laser safety glasses to the patient and operators, displaying laser hazard signage, and inspecting the mechanical aspects of the laser. Once safety systems were in place, the laser was test-fired to insure proper beam function and water spray delivery. The laser pulse rate was set to 30 Hz and the laser energy was set to 180 mJ which yielded a power of 5.4 W. High-volume suction was used continuously to evacuate the laser plume. The laser beam was defocused approximately 2 cm from the target tissue for 90 seconds (Figure 4). The beam was directed closer to the decay with a brushing-like motion until ablation began. The tip was kept in a close noncontact position as the decay was removed until the preparation depth extended close to the pulp. The energy was then lowered to 70 mJ (for a power of 2.1 W) for further caries removal and bacterial decontamination. The preparations were completed (Figure 5) and the teeth were isolated for restoration. Clearfil SE bond (Kuraray America, Inc., New York, N.Y.) was applied to enamel and dentin surfaces and a 0.4-micron filler particle size composite was used as the restorative material. Finishing of the restoration was performed with coarse diamond burs, 12-blade finishing burs, and finishing discs (Figure 6).

D. Postoperative Instructions
The patient was told that she could resume normal activities due to the lack of numbness as a result of no injections. The patient’s mother was told to call the office if pain or any other unusual symptoms occurred.

E. Complications
No complications occurred during or after the procedure.

F. Prognosis
The prognosis for the success of the procedure and restorations is good. The patient and her mother were informed that the lesions were

Figure 4: Laser initially used in a defocused mode, approximately 2 cm from the target teeth

Figure 5: Laser preparations completed

Figure 6: Composite restorations completed
close to the pulp and if the teeth became painful other treatment may be necessary. Otherwise, the restorations should be functional until the time of natural exfoliation of the teeth.

G. Treatment Records
Treatment records, including the details outlined above, were included in the patient’s chart notations.

FOLLOW-UP CARE
A. Assessment of Treatment Outcome
The objectives originally set were achieved. The entire procedure was performed with success without the use of dental anesthetic. Also, satisfactory esthetic and functional results were obtained.

B. Complications
No complications were experienced during or after treatment.

C. Long-Term Results
After 3 months, the restorations were evaluated for integrity and tooth health (Figure 7). The restorations were performing well and the patient expressed no concerns or discomfort.

D. Long-Term Prognosis
It is expected that the restoration performed should last until the teeth naturally exfoliate as her permanent teeth erupt.

AUTHOR BIOGRAPHY
Dr. Alfred Wyatt, Jr. is a graduate of the Medical College of Georgia School of Dentistry where he serves as Associate Professor of Oral Rehabilitation. He maintains a private practice in College Park, Georgia. Currently, he serves on the Board of Directors of the Academy of Laser Dentistry as well as on the American Dental Association working group for laser usage. Dr. Wyatt presently utilizes Er:YAG and diode lasers in his practice and has attained Advanced Proficiency and Certified Educator Status through ALD. Dr. Wyatt may be reached via e-mail: doc2TH@bellsouth.net.

Disclosure: Dr. Wyatt has no financial connections with or interests in any dental companies.

Figure 7: Three-month postoperative view. Teeth are comfortable and functional.

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

ER:YAG LASERS IN PEDIATRIC RESTORATIVE DENTISTRY


This issue provides a sampling of more recent studies describing use of erbium lasers in pediatric dentistry. The first two clinical studies confirm the safety and effectiveness of Er:YAG laser use for cavity preparation in children.

A variety of in vitro studies investigated the marginal microleakage and/or bond strength of restorations placed subsequent to Er:YAG laser-assisted cavity preparation. Some studies compared laser results with other technologies. As might be expected, results varied, and were dependent upon technique and restorative materials used, and whether or not supplemental surface conditioning was employed.

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.

CLINICAL APPLICATIONS OF ER:YAG LASER FOR CAVITY PREPARATION IN CHILDREN

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Objective: The purpose of this study was to determine the clinical usefulness of Er:YAG laser for cavity preparation in children. Background Data: The conventional methods for cavity preparation instill fear and discomfort in pediatric patients. The Er:YAG laser is a new tool developed for cavity preparation; however, there are few reports of its clinical application. Materials and Methods: A clinical evaluation using an Er:YAG laser was carried out using 32 subjects (with 16 deciduous and 19 permanent teeth) with ages ranging from 2 to 12 years. All cavities were restored with light-cured composite resin following the application of bonding agent, but without acid etching or primer conditioning. Results: During laser treatment, the pediatric patients were very cooperative and hardly complained of any pain, and no tooth showed undesirable effects during the 3-year period of observation. Conclusion: It can be concluded from the results of this study that an Er:YAG laser would be a useful alternative method for cavity preparation for composite resin restoration in children.

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Purpose: The erbium:YAG laser has been shown to be safe and effective for caries removal and cavity preparation in adults. In this study, we report a prospective parallel controlled randomized multicenter clinical trial of this laser for dental caries removal and cavity preparation in children. Methods: At two separate sites, a total of 124 patients from 4 to 18 years old, having at least one tooth with caries requiring restoration, were randomized for treatment in a 2:1 ratio, laser to conventional dental drill. Caries were removed, the teeth were restored and follow-up evaluations were completed after 3 months. Determination of safe and effective treatment included four criteria: (1) acceptable caries removal, (2) acceptable cavity preparation, (3) pulp vitality, and (4) intact and serviceable restoration.

Results: All 42 drill procedures and 81 out of 82 laser procedures were found to be successful in terms of safety and effectiveness. No significant difference in pain reported was found between drill or laser treatments, and no complications or adverse events were reported after treatment or at any other time during the study. Subject satisfaction with treatment procedures as reported was equivalent in the laser and drill groups. The only significant difference found between treatment groups was in the greater use of anesthesia during drilling procedures. Conclusions: The erbium:YAG laser is safe and effective for both caries removal and cavity preparation in children.

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Purpose: The purpose of this study was to assess in vitro the influence of 3 cavity preparation devices (carbide bur, Er:YAG laser, and air abrasion) on the microleakage of flowable composite restorations in primary teeth. Methods: Fifteen primary second molars were selected, and Class V cavities were prepared on the buccal/lingual surfaces, being assigned to 3 groups (n = 10). Group 1 (control) was prepared using a high-speed handpiece and was acid etched. Group 2 was prepared and treated with an Er:YAG laser (400 mJ / 4 Hz and 80 mJ / 4 Hz, respectively) and was acid etched. Group 3 was prepared and treated with an air abrasion system and was acid etched. Cavities were restored and stored for 7 days. Restorations were polished, thermocycled, immersed in 0.2% rhodamine B, sectioned, and analyzed for leakage. Results: Er:YAG laser-prepared cavities showed the highest degree of infiltration. The performance of the air abrasion device was comparable to that of the high-speed handpiece. Conclusion: It may be concluded that the method of cavity preparation affected the microleakage of Class V cavities restored with flowable composite in primary teeth.

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**BOND STRENGTH OF A COLORED COMPOMER TO DECIDUOUS DENTIN FOLLOWING TREATMENT WITH CARISOLV, AIR ABRASION, ER:YAG LASER, AND A CONVENTIONAL BUR**

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*J Dent Res 2003;82(Spec Iss B):abstract 2925 (www.dentalresearch.org)*

Objectives: The aim of this study was to investigate whether the shear bond strength of a colored compomer was affected by different methods of caries excavation on the dentine. Methods: 40 freshly extracted human deciduous teeth were divided into three experimental groups and one control group. In the treatment groups (n = 10), the dentine surface was treated with either a chemical method of caries removal (Carisolv), air abrasion, or the Er:YAG laser. Caries excavation was carried out in the control group (n = 10) using the conventional method with a bur. Complete caries removal was ensured as each dentine surface was tested with DIAGNOdent (Kavo, Germany). The surface roughness was evaluated using optical scanning. The teeth were then sectioned into rods and each exposed dentine surface was then bonded with a colored compomer (Twinky Star, VOCO, Germany) using a resin dentine adhesive (Futuabond, VOCO, Germany). Fifty percent of the samples were pretreated with acid etching using 35% phosphoric acid for 30 secs. The bond strength of each sample was evaluated by tensile testing at a cross-head speed of 0.5 mm/min using an Instron machine. Data was analysed statistically. Results: Bond strength after air abrasion and acid etching was significantly higher (p < 0.05) than the other etched groups. Laser treatment with and without etching gave the lowest bond strength. Etching increased the bond strength in conjunction with Carisolv, air abrasion, and the Er:YAG laser but decreased the bond strength in the control group. Conclusions: Air abrasion produced the roughest dentine surface which increased the mechanical retention of the compomer and therefore the shear bond strength. Acid etching increased the bond strength in all experimental groups but lowered the bond strength when a bur was used.

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**MORPHOLOGICAL AND MICROLEAKAGE STUDIES OF THE CAVITIES PREPARED BY ER:YAG LASER IRRADIATION IN PRIMARY TEETH**

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Objective: The purposes of this study were to investigate cavity surfaces morphologically, and compare microleakage at cavities prepared by Er:YAG laser after composite resin restoration versus conventional mechanical treatment in human primary teeth *in vitro*. Background Data: There have been few reports on microleakage at cavities prepared by Er:YAG laser irradiation. Materials and Methods: A total of 30 cavities (class V) in human primary teeth were used. Half of the cavities were prepared by an Er:YAG laser system at 300 mJ pulse energy and 4 Hz, and the other half were prepared with a high-speed diamond bur. Five cavities from each group were investigated by scanning electron microscopy (SEM) and histopathological examination. Remaining cavities were filled with a composite resin without an acid-etching technique and then subjected to microleakage test in 0.6% rhodamine B solution under thermocycling. Results: Microleakage (score: 2.45 +/- 1.07) at cavities prepared by laser was significantly less than that by bur (score: 1.30 +/- 0.95; p < 0.05). SEM observation showed that, compared with the relatively flat appearance of cavities prepared by bur, cavity margins prepared by laser were irregular but there was almost no smear layer at the cavity walls. Conclusion: It can be concluded that cavity surfaces prepared by Er:YAG laser are irregular, but microleakage at cavities prepared by the laser after filling with composite resin is better than that by mechanical bur using the dye penetration method.

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MICROLEAKAGE IN CLASS V RESTORATIONS OF DECIDUOUS TEETH PREPARED WITH ER:YAG LASER

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Objectives: The evaluation of microleakage in class V restorations of deciduous teeth prepared using Er:YAG laser and comparison to the ones observed when conventionally prepared, using composite resin and glass ionomer cement, was the subject of this study.

Methods: The laser used was the KaVo KEY II with wavelength of 2.94 μm, energy of the 300 mJ, repetition rate of 3 Hz, and energy density of 86 mJ/cm². Twenty-eight deciduous teeth were divided into four groups: G1 – prepared with high-speed drill + composite resin; G2 – prepared with high-speed drill + glass ionomer cement; G3 – prepared using Er:YAG laser + composite resin; and G4 – prepared with Er:YAG + glass ionomer cement. After the restoration the specimens were stored at 37° C for 24 hours, thermally stressed, immersed in 50% aqueous solution of silver nitrate for 24 hours while kept in the dark. The specimens were rinsed in water, soaked in photodeveloping solution, and exposed to fluorescent light for 6 hours. After this process the samples were sectioned and observed by stereomicroscopy. For comparison the groups were divided into occlusal and cervical microleakage. The results were analyzed under the Kruskal-Wallis test.

Results: For the occlusal microleakage the statistical significance was 5% among the groups and the average comparison showed higher microleakage for G1 (M = 35.1) than for G2 (M = 24.0) as well as compared to G3 (M = 22.3). The other groups did not present statistical differences among them. For the cervical microleakage the Kruskal-Wallis test did not present any statistical difference. Comparing the occlusal and cervical microleakage data, for every group, using the Wilcoxon test, no statistical differences was observed. Conclusions: This study showed the Er:YAG laser to be effective for class V restorations and to result in a smaller microleakage degree using the composite resin.

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MICROLEAKAGE OF COMPOSITE RESIN RESTORATION IN CAVITIES PREPARED BY ER:YAG LASER IRRADIATION IN PRIMARY TEETH

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Aim: The purposes of this study were to investigate the surface morphology of cavities prepared by Er:YAG laser irradiation and to compare the microleakage degree after composite resin restoration with etched bur cavities in primary teeth, in vitro. Materials and Methods: On the buccal (facial) and lingual (palatal) surfaces of 25 primary teeth, a round cavity was prepared with the Er:YAG laser system and with a high-speed diamond bur, respectively. Five cavities from each group were investigated by scanning electron microscopy (SEM). The remaining cavities were filled with a composite resin and subjected to a microleakage test (0.6% rodamine B solution) under thermocycling. Only bur cavities were acid-etched before filling. Statistical analysis was performed using the Mann-Whitney’s U test; a value of p < 0.01 was considered significant. Results: SEM observation of the laser and etched bur cavities revealed an absence of a smear layer; enamel rods and opening of dentinal tubules were recognized. No statistically significant differences were noted between microleakage of composite resin restorations of the laser and the etched bur cavities. Crosscut sections of the cavities with no microleakage showed good adhesion between the restorative material and dental hard tissues; there was also no gap at the interface. Discussion: The highly irregular surface or the removal of the debris-like smear layer after laser irradiation may facilitate good adhesion of composite resin with enamel or dentine, and these surfaces might play a major role in decreasing microleakage of laser cavities. Conclusion: It can be concluded that cavities prepared by Er:YAG laser are capable of decreasing microleakage of composite resin restorations in primary teeth, and the efficiency is similar to etched bur cavities.

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