Lasers have become widely used in medicine and surgery since the development of the ruby laser by Maiman in 1960. Lasers designed for surgery deliver concentrated and controllable energy to tissue. For a laser to have biological effect, the energy must be absorbed. The degree of absorption in tissue will vary as a function of the wavelength and optical characteristics of the target tissue. If the peak emission of the laser matches the absorption spectrum of one or more components of the target tissue, a predictable and specific interactive effect will occur. Since tissues all have more than one component, the overall effect will be a combination of the effects on each tissue component. As the temperature increases at the surgical site, the soft tissues are subjected to warming (37° to 60°C), welding (60° to 65°C), coagulation (65° to 90°C), protein denaturation (90° to 100°C), drying (100°C), or vaporization and carbonization (over 100°C). Vaporization of tissue begins when cellular water is heated to its boiling temperature (100°C), while other components of the tissue vaporize at higher temperatures.

Ophthalmologists began using the ruby laser in the early 1960s, and now the CO₂, Nd:YAG, Er:YAG, Er,Cr:YSGG, Ho:YAG, and diode lasers are available for dental and medical surgical specialties. The CO₂ and the Nd:YAG are the most commonly used lasers for surgical procedures performed on oral soft tissues, and they were the first to have handpieces adapted for intraoral use.

The characteristics of a laser depend on its wavelength (Table 1). Wavelength affects both the clinical applications and design of the laser. The wavelength of lasers used in medicine and dentistry generally range from 193 nanometers (nm) to 10,600 nm, representing a broad spectrum from the ultraviolet to the far infrared range. The CO₂ and the Nd:YAG, with wavelengths of 10,600 nm (far infrared) and 1064 nm (near infrared), respectively. Since the beams from both of those lasers are in the infrared range, they are not visible. Therefore, these lasers often use a quartz fiber incorporating a 630 nm (red) coaxial helium-neon laser into the device to act as an aiming beam, and thus facilitate use.

The 1064 nm Nd:YAG laser can be transmitted through an optical fiber, allowing the laser delivery device and the fiber to pass through an endoscope or be delivered intraorally via a handpiece. This allows the operator to work in a familiar setting and use a contact mode for tactile sensation. In contrast, the CO₂ laser is absorbed by optical fibers and initially requires delivery through a series of mirrors in an articulated arm. It also requires focusing by lenses in an operating microscope or a handpiece. The development of a more versatile handpiece and of a hollow wave guide technology that allows the beam to be delivered through a flexible tube have facilitated access to virtually all areas of the oral cavity. Substantial data support the application of both the CO₂ and Nd:YAG lasers for oral soft tissue surgery. The CO₂ laser has been utilized for soft tissue surgery, including the oral tissues, since the early 1970s and received safety clearance by the U.S. Food and Drug Administration (FDA) for this purpose in 1976.

CARBON DIOXIDE LASER

With the CO₂ laser, the rapid rise in intracellular temperature and pressure leads to cellular rupture, as well as release of vapor and cellular debris, termed the laser plume. The debris arising from the site of impact, the char, is carbonized tissue by the laser beam. Char formation occurs more rapidly during the continuous wave mode than with pulsed or gated modes. If the char is allowed to accumulate and laser...
Lasers in Periodontics

irradiation is attempted through it, there will be a rapid jump in temperature to 1,500° to 2,000°C and the irradiated site will begin to incandesce to an orange glow, causing extensive thermal damage. Therefore, proper use of the laser requires removal of the accumulated char layer during surgery to reestablish a moist surface for absorption of the laser energy.

The CO2 laser wavelength is readily absorbed by water. As soft tissue is 75% to 90% water, about 98% of the energy is converted to heat and absorbed at the tissue surface with very little scatter or penetration. Thus, only a narrow zone of coagulation necrosis may surround the vaporization of a CO2 laser incision.4,17,18,28,29 In some systems, the laser beam is focused by a lens to converge at a focal point. The beam is smallest in the cross-sectional area at this focal point and then grows larger as it diverges. In the flexible waveguide delivery system, the smallest diameter of the beam is nearest the end of the handpiece tip, beyond which it diverges. This corresponds to 3 to 5 mm from the target tissue.

Therefore, with this CO2 laser, no contact is made with the tissue, and no tactile feedback occurs. Cutting is accomplished by vaporizing tissue along a line, using a focused beam close to the focal point, with a spot size of 0.1 to 1.0 mm. Divergence of the beam beyond the focal point results in a rapid loss of power density and protects the underlying tissue, causing only protein denaturation and coagulation. Blood vessels in the surrounding tissue up to a diameter of 0.5 mm are sealed.4,17,18,28,29 Thus, a primary advantage of CO2 laser surgery over the scalpel is hemostasis and a relatively dry field for improved visibility.

The depth of the laser incision is proportional to the power setting and the duration of exposure.4,15,17 CO2 laser surgery of the oral soft tissues is generally performed with a power setting of 5 to 15 watts, in either a pulsed or continuous mode. The higher energy levels are required to vaporize and remove tissue, while the lower energy levels are used for hemostasis and photocoagulation.

**NEODYMIUM: YAG LASER**

The 1,064 nm Nd:YAG laser will penetrate water to a depth of 60 mm before it is attenuated to 10% of its original strength. Therefore, the energy is scattered in soft tissue rather than being absorbed on the tissue surface as occurs with CO2 laser energy. However, since this wavelength is attracted to colors, in heavily pigmented soft tissue such as skin, scattering is about twice as great as absorption. This heating effect with the Nd:YAG laser is ideal for ablation of potentially hemorrhagic abnormal tissue, and for hemostasis of small capillaries and very small venous vessels. However, the scattering effect increases the difficulty of judging the depth of penetration, particularly in pale colored tissue, since the surface appearance of the tissue is not a reliable indicator of thermal damage. The depth of penetration has been estimated to be $2 \pm 1$ mm in soft tissue.29 A recent study concluded that thermal damage may occur to the underlying bone when the Nd:YAG laser is used at appropriate energy levels during soft tissue ablation.30 A significant increase in intrapulpal thermal damage has also been reported when the device was used to remove the smear layer from tooth roots in vitro.31-33

The ease of application of the Nd:YAG laser through flexible quartz optical fibers has resulted in its widespread use in endoscopy of the respiratory, gastrointestinal, urinary, and gynecological systems as well as its application to arthroscopic temporomandibular joint surgery. Power of up to 100 watts is used for surgery in these applications, with 10 to 20 watts used for photoablation.23 The development of sapphire and ceramic tips for contact use has allowed precise delivery at low wattage settings (3 to 20 watts) and high power density using...
During laser radiation to achieve maximum efficiency is essential to use a water spray to wet the surface of tissue removal with minimal heat generation. The Nd:YAG laser wavelength of 1,064 nm. Therefore, the energy produced at the 2,940 nm wavelength is absorbed by water 15,000 times more than the Nd:YAG laser wavelength of 1,064 nm. Therefore, the tissue destruction caused by the Er:YAG laser is probably not related to thermal effects as with other types of lasers, but to the microexplosions associated with the water evaporation within the cementum and other dental hard tissues.

The erbium:YAG laser utilizes a fiber optic delivery system with an accompanying helium neon laser as an aiming beam, since the wavelength is invisible. It is essential to use a water spray to wet the surface during laser radiation to achieve maximum efficiency of tissue removal with minimal heat generation. The surface is left with an acid-etched appearance microscopically, which enhances the bond strength when used on enamel for cavity preparation.

DIODE LASER

The diode laser has also been introduced over the past few years for dental use, obtaining FDA safety clearance. It also can be delivered through a flexible quartz fiber optic handpiece and has a wavelength of 819 nm. This energy level is absorbed by pigmentation in the soft tissues and makes the diode laser an excellent hemostatic agent. It is used for soft tissue removal in a contact mode, giving a tactile sensation similar to electrocautery. The power output for dental use is generally around 2 to 10 watts and can be either pulsed or continuous mode. The diode laser has been shown to have similar tissue effects as the Nd:YAG laser in comparable studies, with less thermal effects on the deeper tissues.

PRECAUTIONS DURING LASER SURGERY

Precautions should be observed when performing laser surgery (Table 2). The CO2 laser beam may be reflected from shiny metal surfaces such as retractors or mouth mirrors that may cause inadvertent injury to adjacent tissues. Protective eyewear, specific to block the wavelength of the laser in use, should be worn by operator and assistants. When using the carbon dioxide laser, simple infection control lenses or normal eyeglasses are sufficient to deflect the laser beam. However, all other lasers used in dentistry require colored lenses specific to the wavelength in use for proper eye protection. The patient’s eyes, throat, and delicate oral tissues outside the surgical site should be protected from accidental beam impact through use of safety glasses and wet towels or gauze packs. Adequate high speed evacuation should be used to capture the laser plume, which is a biohazard. Crater-like defects in the underlying enamel and cementum have been noted following experimental gingivectomy in dogs, even when tinfoil was used as a shield between the gingiva and the teeth. Clinicians experienced in CO2 laser surgery have emphasized the need for an adequate shield, such as a flat-bladed instrument or silver foil, between the gingiva and teeth. However, with the newer delivery systems, this is less of a concern since the focal distance from handpiece to soft tissue target is only 3 mm.

USE OF THE LASER IN PERIODONTICS

Only a small number of periodontally directed reviews and reports were published in refereed periodontal
Lasers in Periodontics

Academy Report

Table 2.
Lasers and Their Dental Applications

<table>
<thead>
<tr>
<th>Laser Type</th>
<th>Clinical Applications</th>
<th>Precautions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon dioxide laser</td>
<td>Removal of soft tissue by ablation.</td>
<td>Avoid hard tissue contact by laser emission.</td>
</tr>
<tr>
<td></td>
<td>Recommended for gingivectomy, frenectomy, and excision of soft tissue pathology (both benign and malignant). Also used for laser dehiscence of flaps during and after surgery.59,68</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Precautions: Avoid hard tissue contact by laser. Use expanded margins when performing a laser excisional biopsy to prevent fulguration of diagnostic areas.74 Tissue penetration from laser irradiation will be approximately 0.5 mm deep, depending on power density; very little heat damage occurs below visual depth of wound.59</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Neodymium:YAG laser</td>
<td>Avoid hard tissue contact by laser. Same precautions as listed for CO2 laser.</td>
</tr>
<tr>
<td></td>
<td>Clinical applications: Removal of soft tissue by ablation. Recommended for gingivectomy, frenectomy, and excision of soft tissue pathology, especially hemorrhagic lesions. Also used for laser subgingival curettage procedure.77,103</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Precautions: Avoid contact with hard tissues. May damage root cementum and bone during subgingival curettage. Tissue penetration is less than comparable Nd:YAG effects, with potential for heat damage to underlying bone reduced.43,103</td>
<td></td>
</tr>
<tr>
<td>Diode laser</td>
<td>Clinical applications: Removal of soft tissue by ablation. Recommended for gingivectomy, frenectomy, and excision of soft tissue pathology, especially hemorrhagic lesions. Similar applications as Nd:YAG laser.62,63 Used for laser-assisted subgingival curettage and periodontal pocket disinfection.99,106</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Precautions: Avoid contact with hard tissues. May damage root cementum and bone during subgingival curettage. Tissue penetration is less than comparable Nd:YAG effects, with potential for heat damage to underlying bone reduced.43,103</td>
<td></td>
</tr>
<tr>
<td>Erbium:YAG laser</td>
<td>Clinical applications: Cavity preparation of incipient caries. Root preparation similar to acid etching following root planing.60,54,55,64 Has not been studied extensively for soft tissue applications.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Precautions: Must use adequate water spray when cutting hard tissues with laser. Minimal heat damage reported when used on dental hard tissue at appropriate power densities.41,63</td>
<td></td>
</tr>
</tbody>
</table>

Lasers have been demonstrated to have an ablative effect on dental hard tissues.54,55,93-98 However, there is evidence that lasers, either in contact or non-contact delivery, have any value in root debridement in vivo. The application of the Nd:YAG laser to root surfaces results in alterations in root surface protein to mineral ratio, affects the ability of fibroblasts to attach in vitro, and alters the nature of the smear layer following conventional scaling and root planing.51-55,58 Neither the diode nor Nd:YAG laser was effective in removing calculus from the root surface and should not be seen as an alternative therapy for root planing.51-55,58

Some reports suggest that laser-created wounds heal more quickly and produce less scar tissue than conventional scalpel surgery.7,82 However, contrary evidence from studies in pigs,74 rats,17,83,84 and dogs85 indicates that the healing of laser wounds is delayed, that more initial tissue damage may result, and that wounds have less tensile strength during the early phase of healing.86 Ultimately, the tensile strengths of scalp and laser produced wounds are comparable.86 The use of low-level laser irradiation to improve wound healing has been suggested,87,88 but results to date are inconclusive.89-91 An experiment with cultured human skin fibroblasts showed that collagen production and DNA synthesis were delayed when the fibroblasts were exposed to Nd:YAG laser radiation.92

Hard Tissue Applications

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Several publications in the periodontal literature have evaluated the affect on hard tissues and bone when subjected to laser irradiation.55,65,68,73 Studies have confirmed the negative effects of the Nd:YAG and CO2 lasers when used directly on bone or root surfaces. These negative effects include thermal damage to underlying bone when these lasers are used on soft tissues to perform gingivectomies.30,64,69 In addition, the residual char formation that is produced during laser ablation of the hard tissues has been shown to inhibit attachment of fibroblasts and delay wound healing.54,70

journals prior to 1995.9-12,48-61 However, several laser related studies have appeared in the periodontal literature in the last few years.30,43,44,62-73 Earlier papers advocated the utility of both the CO2 and the Nd:YAG laser for soft tissue procedures.20,25,57,74,75 There is abundant evidence to indicate that there is markedly less bleeding,9,25,71 particularly of highly vascular oral tissues during laser surgery.76-81 Anecdotal remarks that suggest incising oral soft tissue with a laser is less painful than incising such tissue with a scalpel and requires less local anesthesia have not been scientifically validated.29 Reduced postoperative pain from oral and otolaryngological surgical procedures also has been claimed after laser tissue ablation.16 It is theorized that this pain reduction may be due to the protein coagulum that is formed on the wounds surface, thereby acting as a biologic dressing and sealing the ends of the sensory nerves.16

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The erbium:YAG laser has demonstrated the best application of laser use directly upon hard tissue, leaving the least thermal damage and creating a surface that suggests biocompatibility for soft tissue attachment.\(^{67,68}\) Studies have demonstrated the ability of the Er:YAG laser to remove lipopolysaccharides from root surfaces, facilitate removal of the smear layer after root planing, remove calculus and cementum, and leave a surface similar to an acid-etched appearance with a scale-like texture.\(^{59,67,68}\) The effects on the root surface from this laser show an absence of melting, charring, and carbonization (char formation) as seen with the Nd:YAG or CO\(_2\) lasers.\(^{68}\)

However, any additional benefits of the Er:YAG laser to root surfaces compared to root planing alone have not been substantiated. Damage to the cementum surface occurs from laser irradiation despite water coolant, and no publication has shown attachment of human gingival fibroblasts to a root surface previously treated by the Er:YAG laser.\(^{43}\)

Recently the FDA has awarded safety clearance for the use of the erbium, chromium:YSGG laser for laser cutting, shaving, contouring and resection of oral osseous tissues.\(^{99}\) However, there are no published reports of its use in periodontal surgical procedures, nor is there evidence from previous animal or human studies to suggest that this methodology is superior to conventional osseous surgical techniques.\(^{100}\)

Preliminary evidence has been reported that the laser may be useful for treatment of dentinal hypersensitivity.\(^{101}\) Also, root conditioning in periodontal therapy may eventually be accomplished by laser application,\(^{43,58}\) but this requires further investigation.

### Soft Tissue Applications

Traditional use of lasers for soft tissue ablation includes gingivectomy, frenectomy, removal of mucocutaneous lesions (both benign and malignant), and gingival sculpting techniques associated with implant therapy and mucogingival surgery.\(^{9,13-15,20,21,29,46-50,62,78,79}\)

Additionally, several authors have found the laser removal of drug-induced gingival overgrowth to be an advantage over other surgical techniques.\(^{11,12,74,102}\)

Although the carbon dioxide laser is contraindicated for direct hard tissue application, it has been shown to enhance periodontal therapy through an epithelial exclusion technique in conjunction with traditional flap surgery procedures. It has been demonstrated that the CO\(_2\) laser can be used to deepithelialize the mucoperiosteal flap during surgery and when repeated at 10-day intervals following surgery, it has enhanced reduction in periodontal probing depths.\(^{52,63,71,72}\) This technique requires further study using controlled clinical trials with larger sample sizes to substantiate its use as a recommended procedure for enhancing periodontal regeneration.

Case reports have recommended the diode laser (819 nm wavelength) along with the Nd:YAG for treatment of periodontal pockets by laser subgingival curettage or excisional new attachment procedure. However, these case reports offer no evidence to support the contention that these procedures are superior to conventional scaling and root planing. Furthermore, there are no evidence-based clinical trials to substantiate the clinical benefits of laser-assisted subgingival curettage. In addition, the presence of root surface damage following laser-assisted subgingival curettage has been reported.\(^{61,103}\) The lack of standardization with the laser curettage technique for controlling the amount of laser energy produced is also a concern.

From another perspective, since the diode and Nd:YAG lasers are attracted to pigmentation, it was hypothesized that the pigmented bacteria would absorb the laser energy and be selectively killed. This concept was evaluated in a pilot investigation\(^ {104}\) and a 6-month unblinded controlled study using the diode laser in 50 patients.\(^ {105}\) In the latter study, after initial scaling of the teeth, individuals in the test group that received multiple episodes of laser curettage demonstrated fewer periodontal pathogens than patients in the control group.\(^ {105}\) However, in these studies, the results after scaling and laser therapy were not equivalent to the reduction in microbial flora reported following conventional scaling and root planing in other studies.\(^ {106-109}\)

Several controlled studies have assessed the use of laser therapy combined with conventional scaling and root planing. These investigations demonstrated no benefit or only slightly improved treatment outcomes.\(^ {110-113}\)

### Other Applications

Finally, in addition to their surgical applications, studies have indicated that lasers may be used to detect caries, measure blood flow, and assess tooth mobility.\(^ {49,114,115}\) These are areas of research that may prove to have substantial diagnostic benefits.

### SUMMARY

The decision to use a laser for periodontal surgery should be based on the proven benefits of hemosta-
sis keeping in mind the claimed (but undocumented) advantage of less postoperative pain with gingivectomy, frenectomy, or other procedures. Further peer-reviewed, comparative clinical studies are required to establish the potential of lasers in periodontal therapy. This is particularly true for subgingival applications, e.g., root debridement, soft tissue curettage, and excisional new attachment. Furthermore, no long-term clinical studies have shown that laser therapy alone can effectively be used to treat adult chronic periodontitis. The public and general dental practitioners should realize that FDA safety clearance for laser treatments, consisting primarily of soft tissue removal, do not routinely apply to the treatment of most periodontal diseases.

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