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Lasers in general dentistry

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Describing the use of lasers in a general practice setting is a daunting task. General practitioners should be jacks-of-all-trades. Consequently, a discussion of the use of lasers in a general practice setting must include the following disciplines: surgical and nonsurgical periodontal therapy; fixed, removable, and implant prosthetics; endodontics; cosmetics; oral medicine, surgery, and pathology; pedodontics and orthodontics; and operative dentistry.

The field of lasers in general practice essentially began with the introduction of the Nd:YAG laser in 1990. Before the introduction of this wavelength, most dental lasers used bulky articulated arms as their delivery systems. These articulated arms were not conducive to the practice of general dentistry due to the long learning curve needed to master their use and the difficulty in the delivery of laser energy to the entire oral cavity. The Nd:YAG was the first dental laser to use a fiberoptic delivery system attached to a small handpiece similar in size to a dental turbine. This made the delivery of laser energy to every part of the oral cavity a much easier process. In the decade since its introduction, general practitioners have seen the number of wavelengths and manufacturers available to them increase from one manufacturer of one wavelength to seven manufacturers offering six wavelengths. Table 1 lists the wavelengths and manufacturers currently approved by the Food and Drug Administration (FDA) for sale in the United States. It is beyond the scope of this article to evaluate the effectiveness of each wavelength in a general practice setting; rather, this article discusses the use of dental lasers on a discipline-by-discipline basis.

Nonsurgical periodontics

Many claims have been made of the ability of various wavelengths to improve the gingival index of patients. Articles have been published in non–peer-reviewed journals that have extolled the virtues of particular wavelengths to decrease pocket depth, decrease bleeding upon probing, and improve the overall health of the periodontium [1–4]. It is unfortunate that most of these studies are anecdotal and do not stand up to the scrutiny of scientific methodology. This article describes only verifiable results of peer-reviewed articles in discussing the use of lasers in the practice of general dentistry.

Because periodontal disease is a bacterial infection, therapy over the past decade has focused on bacteriocidal treatment. The use of doxycycline [5–7] and metronidazole [8–10] systemically to fight periodontal bacterial infections is well documented. The use of tetracycline-impregnated cords placed into periodontal pockets [11–13] and the use of minocycline sphericals [14–16] injected into the periodontal pockets also are well documented. Many patients who have chronic periodontal disease are given a small maintenance dosage of tetracycline to be taken twice a day for 90 days or more in an effort to maintain an antibacterial effect in the fight against periodontal disease [17,18]. All of these therapies are based on one primary tenet of periodontal therapy: the removal of bacteria from the periodontium improves overall periodontal health.

Nd:YAG and semiconductor diode lasers have been shown to be active bacteriocidal instruments

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Table 1
Wavelengths currently available for sale in the United States

Wavelength	Manufacturer
Nd:YAG	Biolase
	Lares Research
	Millenium Dental Technologies
Diode	Biolitec[a]
	Biolase
	Hoya/Conbio
	Ivoclar/Vivadent
	Zap Lasers
	OpusDent
CO_2	OpusDent
Er:YAG	Hoya/Conbio
	OpusDent
Er:Cr:YSGG	Biolase

Abbreviation: YSGG, .

[a] The wavelength produced by the Biolitec laser is 980 nm; all other diode lasers produce a wavelength of 810–830 nm.

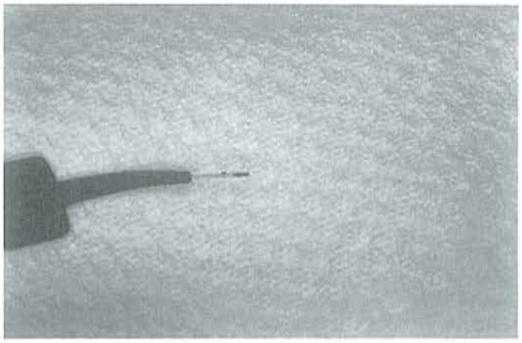

Fig. 2. Granulomatous tissue at end of fiber tip removed from diseased pocket.

against periodontal pathogens in vivo and in vitro [19–23]. In one study, bleeding index improved in 96.9% of the population after laser therapy compared with a 66.7% improvement in the nonlased population [20]. In this technique, laser energy is directed solely onto the soft tissue lining of the periodontal pocket. The optical fibers used to deliver the laser energy are only end-lasing fibers; that is, the energy comes out only from the fiber tip, not along the side wall of the fiber. When the laser energy is directed parallel to the root surface, the laser will remove bacteria and their exotoxins (hyaluronidase, collagenase, and so forth) from the soft tissue that are responsible for breakdown of the periodontium. Bader [24] described the advantage of laser curettage as enhanced bacterial reduction with good hemostasis in a procedure that is less invasive than open flap surgery.

Fig. 1. Diode fiber in the pocket.

Laser energy, however, must not be used directly on the root surface. When laser energy is directed onto the root surface, the root surface can be damaged. Schwartz et al [25] studied the effects of diode laser energy on root surfaces. This study concluded that when laser energy is directed onto the root surface, severe damage including craterlike defects and grooves occurred. Morlock et al [26] found similar results with Nd:YAG lasers. These studies and others [27–31] led the American Academy of Periodontology to conclude that the diode laser and the Nd:YAG laser are not alternatives to root planing [32]. The important fact to note with diode and Nd:YAG intrasulcular treatment protocols, as with most dental laser treatment protocols, is that the laser is used as an adjunct to standard treatments rather than as a replacement for standard treatments. Laser treatment of periodontal pockets will not be successful unless it is combined with standard scaling and root planing to remove bacteria and accretions from the root surface. Conventional instruments are used for standard scaling and root planing procedures and laser energy is used solely on the soft tissue lining the pocket. Bader's [24] description of his technique emphasized that the laser tip is moved circumferentially around the tooth rather than onto the root surface and is followed by hand instrumentation.

Fig. 1 illustrates a diode laser fiber in a periodontal pocket. Note that the fiber is parallel to the long axis of the tooth and the fiber tip does not come into contact with the root surface. Fig. 2 illustrates the fiber removed from the pocket. Note the granulomatous soft tissue removed from the pocket on the end of the fiber.

Nonosseous periodontal surgery

Virtually every soft tissue laser on the market has the ability to perform adequate incisions/excisions of soft tissue. Soft tissue lasers have been used successfully in many types of periodontal soft tissue surgical procedures including gingivectomy and frenectomy. Most soft tissue lasers also are excellent at coagulation/cauterization of wound sites and have documented bacteriocidal properties [19–23]. Wigdor et al [33] described the advantages of lasers over cold steel surgical procedures: (1) dry and bloodless surgery, (2) instant sterilization of the surgical site, (3) reduced bacteremia, (4) reduced mechanical trauma, (5) minimal postoperative swelling and scarring, and (6) minimal postoperative pain.

Fig. 3 illustrates a 27-year-old female whose medical history included a kidney transplant. The patient was taking cyclosporine to prevent rejection of the transplanted tissue. One of the classic side effects of cyclosporine is gingival hyperplasia. Fig. 4 illustrates the maxillary gingiva immediately after carbon dioxide (CO_2) ablation of the gingival hyperplasia. Fig. 5 shows the maxillary gingiva at 1 week postoperatively and the mandibular gingiva immediately preoperatively.

Although the average dentist may not see many organ transplant patients on a regular basis, most dentists have a large number of patients taking calcium channel blockers. The American Heart Association estimates that one in four Americans suffer from hypertension, and calcium channel blockers are the most popular drugs used to combat hypertension [34]. Calcium channel blockers are one of three types of drugs that may cause gingival hyperplasia as an unwanted side effect. Cyclosporine, an immune system suppressant used to prevent rejection in organ transplant patients, and phenytoin hydrochloride (Dilantin), used for seizure disorders, are the other two types of drugs that may cause gingival hyperplasia. Ellis et al [35] observed that 74% of patients taking certain calcium channel blockers had gingival hyperplasia as a side effect. Because many patients taking calcium channel blockers may also be on low doses of aspirin or warfarin sodium (Coumadin), the advantage of the laser as a device with coagulating/cauterizing properties in these anticoagulated patients becomes more apparent. Lockhart et al [36] stated that patients taking aspirin daily should discontinue the aspirin at least 5 days before any elective dental surgery. Discontinuation of aspirin for at least 5 days may not be an option for many cardiac patients seeking dental treatment. For these patients, laser surgery provides a viable treatment alternative to scalpel surgery without alteration of the patient's drug regimen.

Fig. 4. Immediately postoperative view of maxillary gingiva after CO_2 ablation of gingival hyperplasia.

Frenectomy is another periodontal surgery procedure routinely performed by general practitioners. Bader [24] compared laser and conventional (scalpel) frenectomy (Figs. 6–9). He described a conven-

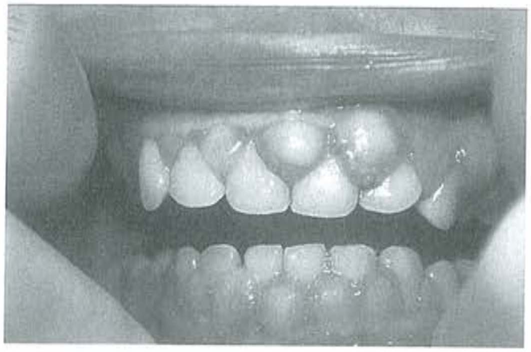

Fig. 3. Twenty-seven-year-old white woman taking cyclosporine to prevent rejection of transplanted kidney.

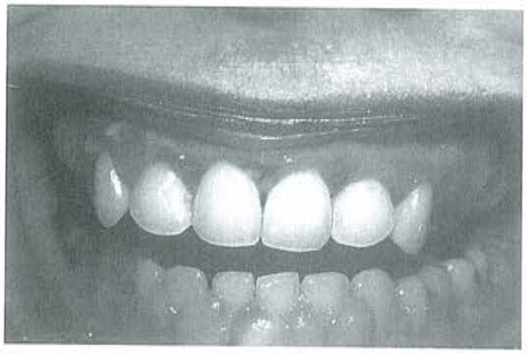

Fig. 5. One-week postoperative view of maxillary gingiva and immediate preoperative view of mandibular gingiva.

Fig. 6. Aberrant frenum pull on lower anterior gingiva.

Fig. 8. One-week postoperative view of frenum site.

tional frenectomy procedure as one that required profound analgesia, scalpel use, and sutures, with a considerable amount of hemorrhage and an uncomfortable postoperative course. He called the use of lasers for frenectomy "a dramatic application," and listed the advantages of laser frenectomy as being bloodless, needing minimal analgesia, producing little or no postoperative discomfort, and requiring no sutures.

Fig. 6 illustrates an aberrant frenum pull on the lower anterior incisors. Note the recession on tooth 25. Fig. 7 illustrates the surgical site immediately postoperatively. Fig. 8 illustrates the site at 1 week postoperatively. Note the return of the gingiva to normal architecture and the lack of pull on the lower anterior teeth. Fig. 9 illustrates the surgical site at 2 weeks postoperatively. Note the healing with no evidence of keloid or scar formation.

Osseous periodontal surgery

The design and raising of a full-thickness mucoperiosteal flap for any surgical procedure, whether for periodontal or oral surgery, is a relatively straightforward procedure. Essentially, the base must be wider than the crest to ensure adequate blood flow to the flap. Most general practitioners have the ability to raise and to suture back into place a full-thickness soft tissue flap. The most difficult step in a typical periodontal surgical procedure—the step that will ultimately determine the success or failure of the surgical procedure—is the removal of the diseased tissue from the surgical site. If the diseased soft tissue and calcified accretions on the root surface are not removed, then the surgical procedure is sure to fail. Many techniques and instruments are available for removal of this diseased tissue. Historically, the instruments of choice have been curettes and other surgical-steel instruments. Lasers are now being used for this procedure. A distinction must be made with respect to the erbium class of dental lasers. There is a great deal of difference between the effectiveness of the Er:YAG laser (2790 nm) and the Er:Cr:yttrium-scandium-gallium-garnet (YSGG) laser (2940 nm) in osseous surgical periodontics. Research has shown the ability of the Er:YAG laser to remove calculus and lipopolysac-

Fig. 7. Immediate postoperative view of frenum surgery site.

Fig. 9. Two-week postoperative view of frenum site.

charides from root surfaces without melting, charring, or carbonization of the root surface [32]. The Er:YAG laser now may be used not only to remove the diseased hard and soft tissue from root surfaces but also to clean out the diseased tissue in root furcations and infrabony pockets without fear of harming the root surface. Whereas other wavelengths that have been studied (eg, Nd:YAG and CO_2) leave a char layer on the root surface that prevents attachment of fibroblasts to the root surface, the Er:YAG leaves a smooth char-free surface with no smear layer and the collagen matrix exposed [37]. The significance of this difference is explained shortly. The ability to leave a smooth char-free surface with no smear layer and the collagen matrix exposed is a great step forward in the use of lasers for periodontal surgery. Dentists using the Er:Cr:YSGG lasers, on the other hand, have yet to report in the scientific literature any use of this wavelength for periodontal osseous surgery. The American Academy of Periodontology stated that even though the Er:Cr:YSGG wavelength has received FDA safety clearance, there are no reports in the literature (animal or human studies) that may be used to defend its use [32].

After a flap is raised and the diseased tissue is removed, many practitioners use a variety of barrier membrane techniques to prevent the epithelium from growing faster than the connective tissue. The principle of epithelial exclusion has been in the periodontal literature for over 50 years [38]. The use of barrier membranes to retard the growth of epithelium has been discussed for the past decade [39]. Exclusion of the epithelium allows the connective tissue to grow, which results in new soft tissue attachment to the root surface. When laser de-epithelialization of flaps is followed by osseous grafts, cementogenesis and osteogenic activity result [40].

The CO_2 wavelength has a unique effect on soft tissue due to its minimal depth of penetration into mucosa. This shallow penetration results in an instant surface vaporization of tissue rather than a deep burn as seen with other, more penetrating forms of laser energy and led researchers to test the idea of using the CO_2 wavelength as an epithelial exclusion device. Multiple studies in monkeys, beagles, and humans have proved the ability of the CO_2 wavelength to safely exclude the epithelium from wound sites of periodontal flap procedures more efficiently and effectively than conventional techniques. These studies have shown that when CO_2-lased sites are compared with nonlased sites in split-mouth experimental designs, the CO_2 sites show better gain of clinical attachment level and increased osseous fill of infrabony defects [40–45]. The benefit of using the Er:YAG laser on root surfaces (in addition to the CO_2 laser) now becomes apparent: the Er:YAG laser may be used to remove diseased tissue from the root surface, leaving the root surface smooth with no char layer and the collagen matrix exposed. The next step in the surgical procedure is de-epithelialization of the external flap margin. This procedure permits the connective tissue to form a new attachment onto the smooth root surface. This double-wavelength surgical technique shows tremendous potential to revolutionize the practice of regenerative periodontal surgery. More split-mouth studies with larger numbers of patients are needed to validate what has been shown in two animal models and small human studies. This technique also has implications beyond periodontal surgery. It may be used to close osseous fenestrations during apical surgery and to increase bone fill during other procedures in which the osseous architecture surrounding teeth needs to be enhanced.

Fig. 10 illustrates a 52-year-old man who underwent osseous periodontal surgery. Note a mass of diseased granulomatous tissue in the furcation of tooth 15. Fig. 11 illustrates the root immediate after laser treatment to remove the diseased tissue. Note the

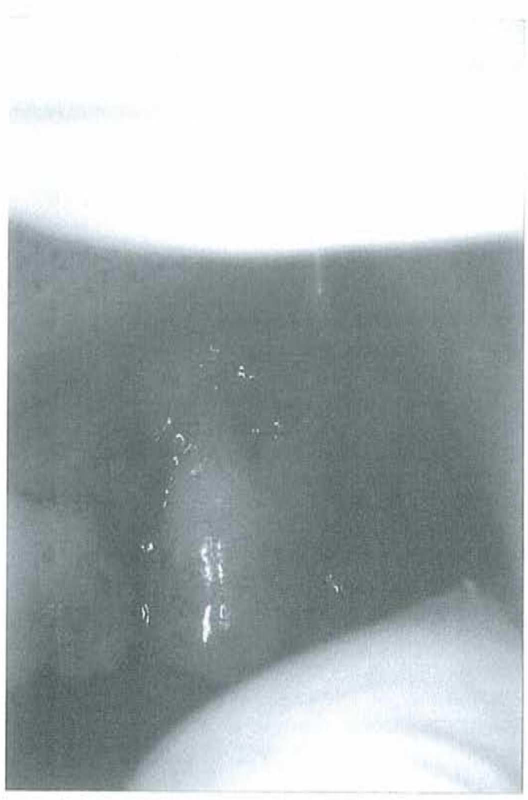

Fig. 10. Granulomatous tissue in furcation of tooth 15.

Fig. 11. Furcation cleared of granulomatous tissue by Er:YAG laser.

smooth root surface with no evidence of carbonization or other damage.

Fixed prosthetics

The two most common fixed prosthetic procedures performed by general practitioners are the single crown and three-unit bridge. Lasers can play a vital role in these procedures. Gingival retraction before making a final impression is a critical step in the fabrication of the prosthesis. Use of electrosurgical and radiosurgical instruments may cause unwanted recession postoperatively, exposing the metal margin of a crown or the sensitive root surfaces in the oral cavity. Retraction cord has been a useful tool for gingival retraction for many years. The purpose of retraction cord is twofold: absorption of crevicular fluid to create a dry field for the impression material, and mechanical separation of the tooth from the gingiva to allow for a sufficient quantity of the impression material to flow into the sulcus. Lasers are now used in place of retraction cord for exposure of gingival margins immediately before impression making. At low power, soft tissue lasers may be used to vaporize the crevicular fluid and desiccate the inner epithelial lining of the sulcus, allowing the introduction of the impression material into the sulcus. Immediately after making the impression, the desiccated tissue rehydrates and there is no resultant recession of the tissue. Fig. 12 illustrates the correct position of the fiber optic of a diode laser entering the sulcus parallel to the long axis of the tooth to create a trough before making an impression for a porcelain-fused-to-metal restoration.

With the introduction of newer generation materials for fixed prosthetics, many dentists are placing ceramic and pressed-composite restorations. These restorations are more conservative than full-coverage restorations and can bear occlusal forces better than large three- or four-surface amalgam preparations. These restorations are usually placed after removal of large old/defective amalgam restorations. In many cases, the gingival seats of these restorations are at or even below the free gingival margin. Packing retraction cord in these areas may prove to be a difficult procedure. Even retraction cord impregnated with racemic epinephrine or astringents such as aluminum chloride or ferric chloride may not do a good job of retracting the gingiva and preventing the flow of blood onto the gingival seat before making the impression. Restorative cases like these highlight the utility of lasers in prosthetic care. Soft tissue lasers may be used in these cases to perform a gingivoplasty at the gingival seat, thereby exposing more tooth structure, and to cauterize the area so that the margins are distinct, clean, and free of blood and saliva.

Occasionally, excess soft tissue around the margin of a preparation may prevent the dentist from

Fig. 12. Fiber optic in position for gingival troughing.

making an adequate impression. In those situations, a clinical crown-lengthening procedure may be necessary. If a significant portion of the clinical crown has broken off, then the procedure might also include an osseous resection. Virtually every soft tissue laser is capable of performing a gingivoplasty around a crown preparation. Erbium lasers also have the ability to perform the osseous resection without raising a flap. This closed osseous resection procedure is a significant advantage over more conventional osseous crown-lengthening procedures. All erbium laser manufacturers provide extremely thin tips that may be introduced into the gingival sulcus. These tips may be used to remove the soft tissue at the base of the pocket, expose the osseous crest, and perform a very conservative osseous recontouring to expose healthy tooth structure. In addition to the advantages of laser surgery previously discussed by Wigdor et al [33], the major advantage of this closed osseous crown lengthening over the conventional open-flap procedure is the savings in chair time. There is no need to spend time raising a flap or replacing and suturing the flap in place. There also is no need to apply a periodontal dressing to the area. Postoperative visits and after-hours emergency phone calls are kept to a minimum due to laser surgery generally having a more benign course of healing compared with scalpel surgery.

Fig. 13 illustrates a maxillary central incisor sheared off below the gingiva. Fig. 14 illustrates the central incisor after using a CO_2 laser to deepen the sulcus to expose the bone. Fig. 15 illustrates the incisor after an Er:YAG laser removed a thin layer of bone circumferentially around the preparation. Fig. 16 illustrates the central incisor 2 weeks after the combined Er:YAG/CO_2 surgery.

When a fixed prosthesis is made to replace one or more teeth, it is critically important for the pontic to look as natural as possible, with an emergence profile that mimics a natural tooth. Preparation of the pontic site to create a more natural emergence profile is a difficult procedure to perform conventionally. This is a procedure that usually can be quite bloody. Rice [46] described a technique that first uses conventional armamentarium (diamond football bur) to create an ovate pontic site, followed by laser energy for coagulation of the region. Fig. 17 illustrates a six-unit porcelain-fused-to-metal bridge, with a pontic replacing tooth 6. Note the tiny, unaesthetic pontic and the excess soft tissue in the pontic site. Fig. 18 illustrates the pontic site after CO_2 laser recontouring of the pontic site. Fig. 19 illustrates the bridge in place 2 weeks after pontic-site surgery.

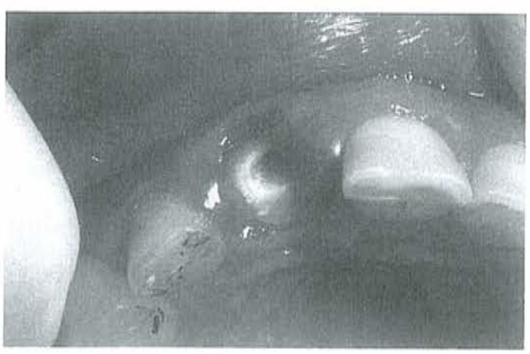

Fig. 13. Central incisor sheared off to the gingiva.

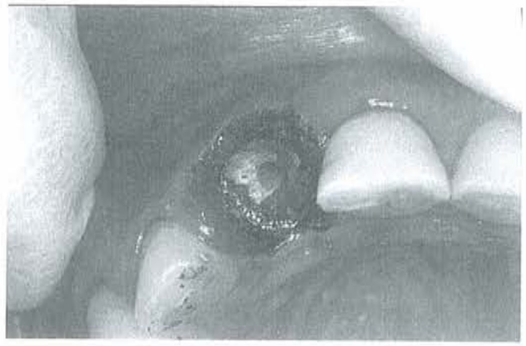

Fig. 14. Deepened sulcus after CO_2 surgery.

Implantology

Lasers play a significant role in the field of implantology. Articles elsewhere in this issue discuss the use of lasers for treatment of peri-implantitis and implant surgery. When making a final impression

Fig. 15. Deepened sulcus after osseous resection by way of Er:YAG surgery.

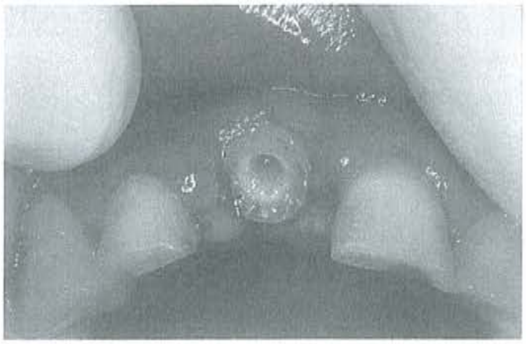

Fig. 16. Two-week view of central incisor.

Fig. 18. Immediately postoperative view of pontic site.

for an implant-supported fixed prosthesis, lasers may be used to modify the soft tissue collar and trough around the implant. In many periodontal and oral and maxillofacial surgery practices, the specialist places the prosthetic abutment on the implant at the second-stage surgery appointment. Often, the restorative dentist must then prepare and modify the abutment and the soft tissue collar. Lasers may be used safely to modify the band of soft tissue around the margin of the implant abutments and to trough around the implant before making the impression.

Fig. 20 illustrates two implants with prosthetic abutments placed by the oral and maxillofacial surgeon. Note the heavy, thick collar of tissue surrounding the abutment, and the diode laser in position to adjust the soft tissue. Fig. 21 illustrates the implants after soft tissue modification and troughing with a diode laser.

Removable prosthetics

Lasers play a significant role in the delivery of superior removable prosthetic care. Lasers are useful at every stage of removable prosthetic care: during preparation of the residual ridge for fabrication of a prosthesis [46–48], at the delivery appointment [47], and at postoperative visits [49–53].

Three significant impediments to the successful placement of a removable prosthesis are bulbous tuberosities, tori that interfere with the path of insertion or cause rubbing against the prosthesis, and excessively flabby ridges that cannot firmly support the prosthesis. Lasers can be used to correct these deficiencies in the ridge and prepare a better bed for placement of the prosthesis. At the delivery appointment for immediate-insertion prostheses, lasers may be used to sculpt the tissue so that the denture fits better. During postoperative visits, lasers can be used to reduce epuli, treat of papillomatosis and denture stomatitis, and perform other surgical procedures that correct hyperplastic reactions to poor-fitting prostheses.

The following case history describes the use of a laser in the delivery of removable prosthetic care.

A 45-year-old patient required replacement of her maxillary partial denture. Clinical and radio-

Fig. 17. Preoperative view of unaesthetic pontic site.

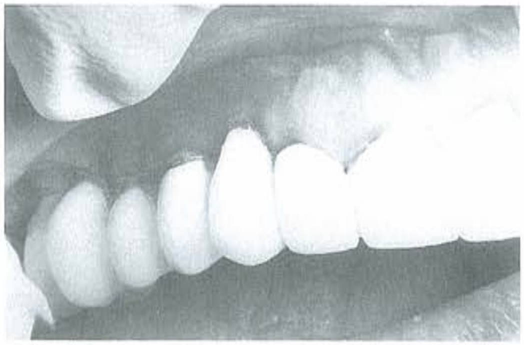

Fig. 19. Two-week postoperative view of pontic site with bridge in place.

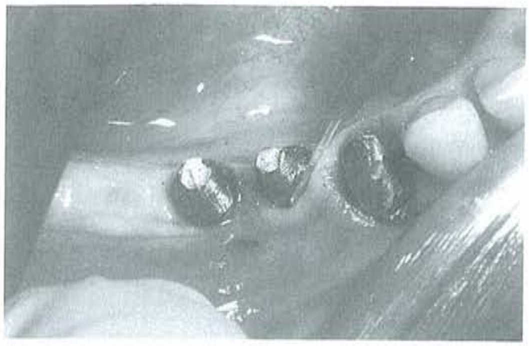

Fig. 20. Diode laser in position around implant posts.

Fig. 22. Preoperative view of maxillary torus.

graphic examination revealed a torus on the maxillary left residual ridge (Fig. 22). It was impossible to fabricate a well-fitting removable prosthesis without impinging on the torus. A CO_2 laser was used to raise a flap around the torus (Fig. 23). After the flap was raised, the torus was reduced with a high-speed round bur, leaving a smooth ridge able to accommodate a partial denture framework (Fig. 24). Fig. 25 shows the surgical site at 1 week postoperatively. This procedure was performed before the FDA approval of the erbium laser for osseous surgery. Had this case presented itself more recently, an Er:YAG laser could have been used to reduce the torus.

Orthodontics

Lasers can play an important role in soft tissue management during orthodontic therapy. Gingival hyperplasia secondary to orthodontic treatment is a common problem seen by the orthodontist and the generalist. The hyperplasia may be a reaction to the metal of the orthodontic appliance; may be due to poor oral hygiene as a result of the appliances, or could simply be because the patient is a mouth breather. There are usually three methods for performing gingival surgery: scalpel, electrosurgery/radiosurgery, and laser surgery.

Electrosurgery and radiosurgery are contraindicated due to the proximity of the hyperplastic tissue to the metal of the braces. Scalpel surgery is a not a realistic option due to the nature of the tissue, which in many cases is thin and friable. This type of tissue would bleed quite easily when excised. The most efficient method of surgery would be laser surgery. Fig. 26 illustrates a 12-year-old girl with poor oral hygiene and hyperplastic gingiva covering the orthodontic appliance. Fig. 27 shows a Nd:YAG laser ablating the tissue. Note the excellent hemostasis during the procedure. Fig. 28 shows the surgical site immediately postoperatively. Lasers also may be used to aid in the exposure of impacted teeth and to modify the soft tissue to aid in orthodontic movement of the teeth. Many dentists perform crestal fiberotomies immediately before at-

Fig. 21. Postoperative view of implant posts after gingivoplasty/troughing.

Fig. 23. CO_2 laser incision to expose torus.

Fig. 24. Immediately postoperative view of torus.

tempting to rotate a tooth. Rather than using a scalpel to cut through these fibers, lasers may be used to ablate the fibers quickly and bloodlessly.

Oral surgery/oral medicine/oral pathology

Lasers have been used in oral and maxillofacial surgery for decades. The first documented use of a laser in oral and maxillofacial surgery was published 1977 [54]. General practitioners are now using lasers for many procedures previously referred to the oral surgeon. In the field of oral medicine, lasers have been shown to palliate the painful symptoms of oral diseases such as aphthous stomatitis [55–57] and systemic diseases with oral manifestations, such as AIDS [58]. General practitioners are now performing many procedures with lasers that they felt uncomfortable performing with scalpels, such as apicoectomies, biopsies, and other minor oral surgical procedures. The reasons that general dentists feel more confident and capable performing these

Fig. 25. One-week postoperative view of torus site.

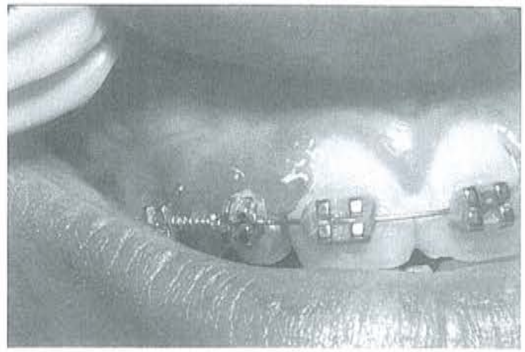

Fig. 26. Preoperative view of orthodontic patient with hyperplastic gingiva.

procedures can be summarized by Wigdor's [33] previously discussed list of the advantages of laser surgery over scalpel surgery.

Cosmetics/esthetics

Lasers are playing an increasingly important role in the field of esthetic dentistry. Although not all researchers agree with its effectiveness, laser bleaching was for a few years an important source of income for many esthetic laser dentistry practices. The goal of laser bleaching is essentially the same as the goal of any so-called "power bleaching" technique: to raise the temperature of the hydrogen peroxide to accelerate the chemical bleaching process. The field of laser bleaching began with the approval by the FDA in 1996 of a dual laser system that combined a CO_2/argon technique along with a patented gel to bleach teeth. Laser companies have FDA approval for marketing their lasers for bleaching, and most diode laser manufacturers highlight the ability to bleach as one of their im-

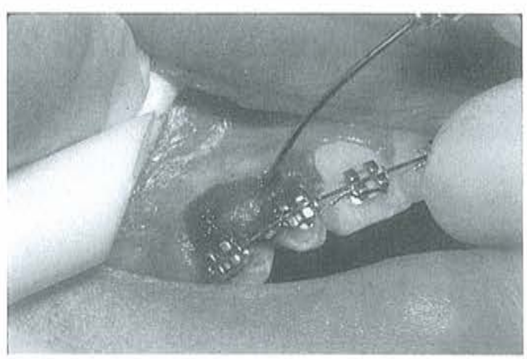

Fig. 27. Intraoperative view of orthodontic patient.

Fig. 28. Immediately postoperative view of orthodontic patient.

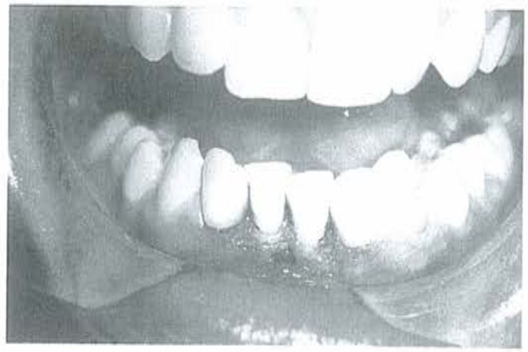

Fig. 30. Lower teeth immediately after cosmetic gingival recontouring.

portant marketing tools. A complete discussion of the chemistry of laser bleaching may be found in a 2002 issue of the *Dental Clinics of North America* [59].

Correction of gingival height discrepancies due to the altered passive eruption of teeth is one of the most common uses of lasers in cosmetic dentistry. Due to the precise nature of their cutting ability, lasers can be used to make very fine modifications to the gingival architecture around teeth without fear of overcutting the gingiva. Fig. 29 illustrates a typical example of the use of lasers in the treatment of altered passive eruption before placement of porcelain laminate veneers. Note the uneven gingival height of the lower anteriors. A diode laser was used to resculpt the lower anterior gingiva and create a more even gingival margin. The lower left central incisor was reduced incisally to create an even gingivoincisal height of the teeth (Fig. 30). Finally, laminate veneers were placed on the lower central incisors to complete the case and present a more harmonious lower anterior soft and hard tissue architecture (Fig. 31).

Operative dentistry

Almost since the profession of dentistry began, dentists have been seeking a method to remove decay painlessly and atraumatically without affecting the surrounding healthy dental tissues. The field of laser operative dentistry began with FDA approval of an Er:YAG laser for caries removal and cavity preparation in 1997. Since that initial approval, three more erbium laser manufacturers have entered the market that advertise their ability to remove diseased hard tissue without the need for anesthesia. These lasers are indicated for all classifications of caries. Erbium lasers are capable of removing not only decayed tooth material but also all nonmetallic restorations. Defective composite, glass ionomer, and

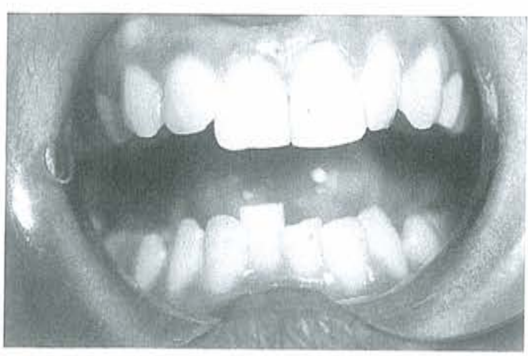

Fig. 29. Preoperative view of lower anterior teeth with altered passive eruption.

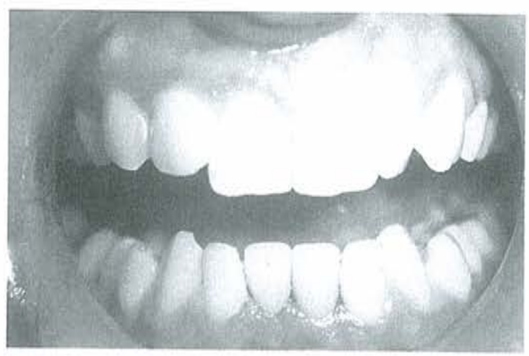

Fig. 31. Two-week postoperative view of lower anterior teeth with porcelain laminates in place.

compomer restorations may be removed quickly and easily without the use of analgesia. The one limitation of erbium lasers is in the removal of metallic and porcelain restorations. There is currently no laser that is able to remove defective amalgam, gold, or porcelain restorations. These restorations must be removed in a conventional manner before the laser can be used on the tooth to remove the recurrent decay.

It is beyond the scope of this article to discuss in detail the process by which erbium lasers remove decay; however, a short explanation of the process of spallation is in order. All dental hard tissues are made of hydroxyapatite. The wavelengths emitted by erbium lasers are preferentially absorbed by water. When erbium lasers are used on any dental hard tissue (enamel, cementum, dentin, or bone), the water in the hydroxyapatite crystal absorbs the laser energy. As the water molecules increase in temperature, they expand tremendously in volume. This volumetric expansion creates tremendous pressure in the hydroxyapatite crystal, and the crystal starts to explode outward. The higher the water content of the hydroxyapetite, the more efficient the ablation process. Because healthy enamel is well calcified, it takes a great deal of energy to ablate it. Decayed enamel has less mineral content and more water content, so the decayed enamel is preferentially removed without any harm to the healthy enamel. During cavity preparation, as the dentin–enamel junction is exposed, the laser begins to ablate hard tissue more quickly because dentin is less calcified (has more water content) than enamel. There is a photoacoustic effect that accompanies hard tissue ablation with erbium lasers. This effect consists of a "popping" sound, similar to making microwave popcorn. As dentists become more experienced with the use of the erbium lasers, they can use this photoacoustic "popping" as a barometer of how well calcified the tooth structure is and whether decay removal is complete. In the nineteenth and twentieth centuries, dentists checked for removal of decay from a cavity preparation by running a sharp explorer over the surface of the cut tooth structure. A dentist who performs laser operative dentistry in the twenty-first century can judge the completion of caries removal by a change in the frequency and pitch of erbium popping. To date, over a dozen clinical studies have been published on the subject of the need for local analgesia with the use of erbium lasers. Most studies describe the need for injection in only 2% to 10% of patients [60,61].

Fig. 32. Preoperative view of defective distolingual composite restoration.

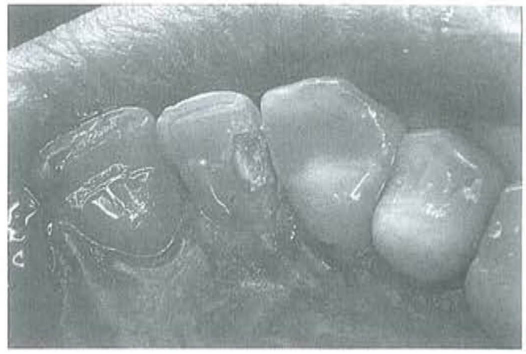

Fig. 33. Postoperative view of excavated distolingual preparation by way of erbium laser.

Fig. 32 illustrates the typical use of an Er:YAG laser on hard tissue. A 64-year-old white man presented with a missing front tooth filling. Clinical examination revealed a missing distolingual restoration with recurrent decay on tooth 7. Fig. 33 shows the completed cavity preparation and etching of the lesion with the Er:YAG laser. No anesthetic was used for this procedure.

Endodontics

Due to the bacteriocidal property of laser light, dentists have been intrigued with the idea of placing laser energy into an infected root canal and clearing out the infected tissue. This dream of laser endodontics is growing closer to reality every day. Lasers have shown tremendous ability not only to clean out and sterilize root canal systems but also to enhance the obturation of the root canal system.

The goals of endodontic therapy may be summarized as follows:

1. Debridement of the canal
2. Instrumentation of the canal
3. Removal of the smear layer
4. Sterilization of the canal
5. Sealing of the main and all accessory canals

After the canal is debrided and instrumented, the critically important step in endodontics that determines the success or failure of the endodontic procedure is the sterilization of the root canal system. A landmark experiment by Kakehashi et al [62] with germ-free rats stands as definitive proof that bacteria are essential for the development of periapical pathology. After bacteria are removed from the root canal system and the system is sealed off, the periapical pathology will heal. It is important to remove the smear layer from the root canal system because the smear layer occludes the dentinal tubules. It is within these tubules that bacteria may be multiplying. When the microorganisms are not removed from the tubules, this could lead to failure of the endodontic treatment. Smear layer removal allows for superior cleaning and sterilization of the root canal. Investigators compared 17% EDTA, a chelating solution commonly used in endodontics to enlarge canals and remove the smear layer, with 6% phosphoric acid and Er:YAG laser energy. The results showed that Er:YAG treatment was the most effective of the three techniques in removal of the smear layer from the canal wall [63–66]. After the smear layer is removed, the dentist must then make certain that there is a bacteriocidal effect in the canal. Research has shown that the Er:YAG laser exerts a significant bacteriocidal effect within the root canal [67,68]. The sole remaining step in endodontic therapy is the obturation of the canal. Er:YAG lasers have shown a remarkable ability to enhance the results of the obturation process. Application of Er:YAG energy to root canal walls has been shown to increase the adhesion of epoxy-based root canal sealers (AH26, AH Plus (Dentsply Mfg., Milford, Pennsylvania), and others) to the canal walls [69]. Current techniques in laser-assisted endodontics, therefore, may be summarized as follows: first, debride and instrument the canals in the usual manner with rotary instrumentation. Second, use the laser to remove the smear layer and destroy the bacteria in the root canal system. Finally, seal the sterile root canal system with a superior bond of the root canal sealer to the dentinal walls. Laser companies are conducting research into the use of lasers as a replacement for rotary and hand instruments to instrument the canal. In the near future, laser endodontics could conceivably be the standard of care.

Summary

Due to their bacteriocidal and coagulative properties, soft tissue lasers have made a significant impact on the delivery of dental care in the twenty-first century. Dentists are now able to perform procedures that they otherwise would have referred to specialists. Soft tissue lasers have enabled dentists to deliver superior care in a less traumatic, more antiseptic surgical field. The surgical field is cleaner, with less blood to obscure the surgeon's field of vision. Hard tissue lasers have the ability to remove carious tooth structure without harming healthy tooth structures or devitalizing the pulp. Operative dentistry may now be performed without analgesia on virgin lesions and on recurrent decay underneath nonmetallic restorations. Minor osseous surgeries may also now be performed with laser energy. The next decade will see even more growth in the field of laser dentistry.

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