Dentistry has a new weapon in the fight against tooth decay. This “light saber” of dentistry is the erbium laser. The dental laser is the latest in modern innovations for the 21st century. The erbium lasers have proven safe and effective for the removal of tooth decay and cavity preparation in addition to many soft-tissue and hard-tissue surgical procedures. The Food and Drug Administration has approved the erbium laser for marketing in the United States as of 1997. The erbium laser offers an alternative to the high-speed drill, eliminating fear and patient discomfort, for both adults and children. The laser is revolutionizing dental care, just as it has in so many other areas of our lives. With the erbium laser, the dentist can provide a new method of dental care, which can often be performed, in many cases, without local anesthesia (Figure 1).

Most patients find laser procedures remarkably comfortable. So comfortable, in fact, that in many cases, no anesthesia is required (Figure 2). People who have experienced laser treatment for cavity preparation report feeling nothing more than the touch of the handpiece and an occasional slight sensation of warmth. Teenage patients report a “tingling” feeling. Unfortunately, conventional drilling must still be used for the removal of previous metal restorations. The Waterlase™ has been used to prepare crowns and veneers without the aid of conventional rotary instruments.¹

The dental laser often eliminates the unpleasant aftereffects associated with many dental procedures: soreness, bleeding, inflammation, sutures, and numbness. It also creates no known aftereffects of its own. The advantage of laser surgery is the minimization of intraoperative hemorrhage and decrease in postoperative pain symptoms.² The carbon dioxide and Nd: YAG lasers have been used effectively for soft-tissue oral surgery procedures. Argon lasers have also been used in oral surgical procedures. One of the main advantages of laser surgery over conventional excision with scalpel is the reported lessening of postoperative pain and the ability to excise or ablate with less bleeding² (Figure 3).

**CLINICAL USES FOR THE EBRIUM LASER**

The erbium laser has various uses that can be divided into hard and soft-tissue procedures for dentistry.

The hard-tissue laser dentistry includes the use of the laser for class I through class VI preparation of carious teeth. The main advantages of the erbium laser for this use are the following:

- No anesthesia is needed for most patients because of the numbing effect of the laser.
- For most patients, no waiting is needed for the patient to be anesthetized.
- No concern exists about the patient biting his or her lip, cheek, or tongue.
- The patient’s experience is more pleasant as a result of not being anesthetized.

The erbium laser can be used for soft-tissue surgery which includes the following:

- gingivectomy
- frenectomy (labial and lingual)
- gingivoplasty
- exposure of teeth to aid tooth eruption
- operculectomy
THE ERBIUM LASER: THE "STAR WARS" OF DENTISTRY

Figure 1. Class III preparation with the Waterlase MD. No anesthetic was used.

- gingival removal to expose areas for restorations
- aphthous ulcers (Figure 7)
- pulp therapy
- abnormal gingival architecture associated with orthodontic movement
- excision of soft-tissue tumors, including fibromas, lipomas

TYPES OF ERBIUM LASERS

Paghdiwala, in 1988, tested the ability of the erbiunm:YAG laser to ablate dental hard tissues. He prepared holes in enamel and dentin with low energy. Without water cooling, the cavities exhibited no cracks and little or no charring. The erbium:YAG (2.94 µm) laser was approved for marketing by the US Food and Drug Administration in May 1997. This laser wavelength was shown to produce precise ablation of sound and carious dentin and enamel with a thermal penetration of shallow proportions. The erbium chromium:YSGG (2.78 µm), made of erbium, chromium, yttrium, scandium, gallium, and garnet, has the same properties as the erbium: YAG laser.

Figure 2. Er,Cr:YSGG Waterlase MD (left). Note the illumination. Class II preparation with no anesthetic, no handpiece (right).

MECHANISM OF ACTION ON HARD TISSUE

According to Hadley et al., the mechanism of action on the hard tissues of the human body (ie, enamel, dentin, cementum, and bone) is that the erbium laser "delivers photons into an air-water spray matrix with resultant microexplosive forces on water droplets. This process is hypothesized to contribute significantly to the mechanism of hard-tissue cutting" (Figure 2).

"Both the Er:YAG and the Er,Cr:YSGG can be categorized as having photomechanical effects. Laser light that is highly energetic and is short pulsed causes fast heating of the dental tissue in a small area. A fast shock wave is created when the energy dissipates explosively as a volumetric expansion of the water occurs. This is called cavitation. Water molecules in the target area are superheated, explode, and thus ablate the tooth structure and cavities. A bactericidal effect, typical of laser-tissue interaction also occurs. The shock waves that occur are due to a rapid photovaporization of water, producing a volumetric change of state of the liquid within the tooth. This change creates high pressures, removing and destroying selectives areas of adjacent tissue. The photono-acoustic effect that develops is characteristic of a short interaction time (100 microseconds) and a high energy density. The incident laser energy is absorbed in a thin surface layer. Water, hydroxyapatite, and collagen have an affinity for this laser energy. The water spray of the laser handpiece accelerates this effect. Water-mediated explosive tissue removal has been shown to be the most efficient way of removing tissue, while transferring minimal heat to the remaining tooth."

Scanning electron microscopy has shown that the erbium laser "makes clean cuts through enamel and dentin without creating a significant smear layer."

Figure 3. Waterlase MD preparing primary first molar for vital pulpotomy.

Figure 5. Waterlase MD (left); immediately after surgery (right). Note no bleeding.

Figure 4. Ankyloglossia.

Figure 6. Twelve-year-old female with gingival hyperplasia (left); immediately after gingivectomy with Waterlase MD (upper right); 1 month after surgery (lower right).
pulsion causes the surrounding material literally to explode away.76

The erbium laser is slower in cutting through enamel than dentin. This is because there is more water in dentin than enamel and more water in carious dentin, the ablation of each of these tissues occurs at a varying rate. The erbium lasers were shown to cut dental hard tissues with efficacy and depth that correspond to the increasing power setting and use of a water spray.7

ETCHING OF THE ENAMEL SURFACE

Lased tooth surfaces were evaluated for their ability to form adhesion with various bonding agents; shear and tensile strength assays were used to compare bonding with lased and acid-etched enamel and dentinal surfaces.4 The etching of enamel and dentin by the erbium laser was shown to be “facilitated or even improved over acid etching techniques.”7 In a study performed by Visuri et al.8 the laser-sampled dental surfaces had improved bond strengths when compared with acid-etched and handpiece controls. Scanning electron microscopic photographs were used to conclude that the erbium:YAG laser preparation of dentin left a surface for strong bonding or composite material.8 Frentzen3 reported that the surface structure of enamel remained rough after erbium:YAG preparation. The laser treatment “allowed additional etching, resulting in a microretentive pattern.”3

PULPAL TOLERANCE

No odontoblastic alterations were noted or any inflammatory response in the pulp chamber beneath the preparation.7 Histopathologic studies in animals and humans showed that pulpal tissues underlying deep cavity preparations made with an erbium laser do not undergo pathologic changes. It was shown, using rats’ teeth, that the fibroblast proliferation was observed sooner and more frequently in the specimens treated with the erbium:YAG laser than those prepared with the high-speed drill.9 Also, Rizoiu et al.10 found that the laser-powered erbium:chromium: YSGG, when used for preparation of carious lesions, had “no apparent adverse thermal effect as measured in the pulp space.” Coluzzi6 stated that “laboratory studies indicate that the pulpal temperature of the treated tooth may actually decrease by 5 degrees Centigrade during laser treatment.” The efficiency of ablation by the erbium:YAG laser has been explained as a “thermally induced mechanical process... the incident Er:YAG laser radiation is absorbed in a thin surface layer, causing sudden heating and vaporization of the water. A high steam pressure then leads to microexplosions with erupting particles with a crater corresponding morphology. Because the tissue is not vaporized completely but only disintegrated into fragments, the radiant energy is converted efficiently into the ablation that alters the morphological structure of the tissue. No melting process takes place that might lead to considerable heat damage to the surrounding tissues.”35

PRECISION OF THE ERBIUM LASER IN CUTTING TOOTH STRUCTURE

Keller and Hibst12 showed that the erbium laser can be applied to both primary and secondary carious lesions. It can also effectively remove cements and composites with ablation efficiency similar to that of healthy tooth structure.31 Previously placed dental sealants can also be removed with the laser. Dental restorative preparations are possible, and, although not as precise as with a bur, these preparations can be improved by limited hand instrumentation, which should allow for successful placement and retention of dental and restorative materials7 (Figure 2).

COMFORT OF THE PATIENT: HANDPIECE COMPARED WITH ERBIUM LASER

The noncontact laser preparation seems to be comfortable to patients, whereas drilling may cause pain sensations because of vibration, pressure, heat, and noise. In an article by Hadley et al.,4 intraoperative discomfort levels indicated a higher prevalence of discomfort among the air turbine or bur-treated teeth than among the erbium laser-treated teeth. Keller and Hibst10 reported on two clinical studies. In the first study, 67 teeth of 33 patients were prepared with an erbium:YAG laser. Buccal preparations were used for that study. In all 67 treatments, no pain was reported in 24 teeth and minimal pain
in 38 teeth. In 29 of 41 teeth with deep cavities, only minimal discomfort was reported. In a second study, the pain of the laser and mechanical drilling was compared. Only 6% of the patients required local anesthesia with laser preparation, compared with 11% of the patients with drilled cavity preparations. Eighty-three percent of the patients indicated that the bur was more uncomfortable than the laser; 88% of the patients indicated a preference for the erbium:YAG laser. The pain perception during laser treatment was reduced; the pain was described as only like short needle sticks."\(^3\)

OTHER EFFECTS OF THE LASER ON THE TOOTH

Caries Prevention

Hicks\(^3\) reported the effect on caries-like lesions and progression in enamel after the use of the argon laser. The resulting surfaces were shown to have a lowered pH from 5.5 to 4.78. This hardened enamel was 4 times more resistant to acid dissolution. The increase in resistance caused a significant reduction in the depth of the carious lesion. Theorizing, the enamel microcavities may trap the ions released (calcium, phosphate, fluoride) that become dissolved during the formation of caries. Enamel that has been lasered has a greater attraction for the calcium phosphate and fluoride ions, with the result of a repopulation of the mineral phase. Therefore, irradiation by laser may be important in caries prevention in enamel that is sound.\(^3\)

Histologic Effects

Effects observed by both the lased and the control groups showed no significant differences in the quantitative effects on the odontoblasts, predentin, and dentin, which showed mild changes in both groups. When the conventional drill was used, the histologic variations were larger for the pulpal tissue, odontoblasts, and predentin. The immediate and long-term effects of the erbium laser for caries removal, preparation of the cavity, and etching of the enamel have shown no significant differences. These variations suggest to me that the dental drill may be more harmful to the tooth than the erbium laser. The localized areas of healing seen within the pulp adjacent to the cavity preparations should be considered a normal physiologic response. No significant damage to the pulp was observed on examination histologically in teeth in which it appeared radiographically that the laser cavity preparation reached the pulp. "The laser may have a potential bactericidal and sealing effect on the pulp when exposed"\(^14\) (Figure 3).

MECHANISM OF ACTION ON SOFT TISSUES

The erbium:YAG laser has indications in soft-tissue surgery if no coagulation effect is desired (i.e., removal of hyperplastic gingival tissue, periodontal surgery, and ablation of large benign lesions of the oral mucosa or the skin, without closing the wound by sutures), according to Keller and Hibst\(^2\) (Figure 9). After focused Er:YAG laser irradiation, small and deep cuts with partial bleeding are seen. Shallow and large lesions are produced by defocused irradiation. In all cases, only a minimal damage zone of carbonization occurs. Two days postoperatively, the wounds are closed in the epithelial parts. Eight days postoperatively, the epithelial wound healing is complete (Figure 8). The subepithelial fibrous tissue is not totally repaired at this time. This corresponds to normal wound healing after surgical incision or excision by scalpels. In contrast, the carbon dioxide laser cuts show a delay in wound healing of 2 to 3 days because of the extended thermal damage zones.\(^5\)

References