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 modern innovation for the 21st Century. 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 FDA approved the erbium laser for marketing in the United States in 1997. It offers an alternative to the high-speed drill, eliminating fear and patient discomfort for both adults and children. The laser is revolutionising dental care – just as it has in many other areas of our lives. With the erbium laser, the dentist can provide a new method of dental care that can often be performed without local anaesthesia (Figure 1).

Most patients find laser procedures remarkably comfortable. So comfortable, in fact, that in many cases no anaesthesia 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 erbium laser has been used to prepare crowns and veneers without the aid of conventional rotary instruments (Nash, 2002).

The dental laser often eliminates the unpleasant after-effects associated with many dental procedures – soreness, bleeding, inflammation, sutures and numbness. It also creates no known after-effects of its own. ‘The advantage of laser surgery is the minimisation of intra-operative haemorrhage and a decrease in post-operative pain symptoms. 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 conventional excision with scalpel is the reported lessening of post-operative pain and the ability to excise or ablate with less bleeding’ (Rizoiu et al, 1996) (Figure 3).

Clinical uses for the erbium laser
The erbium laser has various uses, which can be divided into hard and soft tissue procedures for dentistry.

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 in the majority of patients due to the numbing effect of the laser
- No waiting for the patient to be anesthetised in the majority of patients
- No concern about the patient biting their lip, cheek, or tongue
- More pleasant experience, due to not being anesthetised.

The erbium laser can be used for soft tissue surgery in many ways. These include:

- Gingivectomy (Figure 5)
- Frenectomy (labial and lingual)
- Gingivoplasty
- Exposure of teeth to aid tooth eruption
- Operculectomy
- 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, etc (Convissar, 2000).

The types of erbium lasers
Pagdhiwala, in 1988, tested the ability of the erbium:YAG laser to ablate dental hard tissues. He prepared holes in enamel and dentine 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 (2.78um) is made of erbium, chromium, yttrium, scandium, gallium and garnet, and has the same properties as the erbium:YAG laser (Convissar, 2000) (Figure 2).

Mechanism of action on hard tissue
According to Hadley et al, the mechanism of action on the
hard tissues of the human body (i.e. 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 hypothesised to contribute significantly to the mechanism of hard-tissue cutting.’ (Hadley et al, 2000) (Figure 2)

‘Both the Er:YAG and the Er;Cr:YSGG can be categorised 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 shockwave 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 caries. A bactericidal effect, typical of laser/tissue interaction, also occurs. The shockwaves that occur are due to a rapid photovapourisation of water, producing a volumetric change of state of the liquid within the tooth. This change creates high pressure, removing and destroying selective areas of adjacent tissue. The photoacoustic 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.’ (Miserendino and Pick, 1995)

Scanning electron microscopy (SEM) has shown that the erbium laser ‘makes clean cuts through enamel and dentin without creating a significant smear layer’ (Hadley, 2000). The mechanism of action of the erbium laser is that: ‘Water that is bound to the crystalline structures of the tooth absorbs the laser light readily and easily. The vapourisation of the water within the mineral substrate causes a massive volume expansion, and this expansion causes the surrounding material to literally explode away.’ (Coluzzi, 2000)

The erbium laser is slower in cutting through enamel
than dentine. This is due to the fact that there is more water in dentine than enamel and more water in carious dentine, so the ablation of each of these tissues occurs at a varying rate. Erbium lasers have been shown to cut hard dental tissues with efficacy and depth that corresponds to the increasing power setting and use of a water spray (Eversole and Rizoiu, 1995).

Etching of the enamel surface

Lased tooth surfaces have been evaluated for their ability to form adhesion with various bonding agents; shear and tensile strength assays have been used to compare bonding to lased and acid-etched enamel and dentinal surfaces (Hadley, 2000). The etching of enamel and dentine by the erbium laser has been shown to be ‘facilitated or even improved over acid etching techniques’ (Eversole and Rizoiu, 1995). In a study performed by Visuri et al in 1996, the laser sampled dental surfaces had improved bond strengths when compared to acid-etched and handpiece controls. SEM photographs were used to conclude that erbium:YAG laser preparation of dentine left a surface for strong bonding or composite material. Frentzen reported the surface morphology of enamel remained rough after erbium:YAG preparation. The laser treatment ‘allowed additional etching, resulting in a microretentive pattern’ (Convissar, 2000) (Figure 9).

Pulpal tolerance

No odontoblastic alterations have been noted, nor is there any inflammatory response in the pulp chamber beneath the preparation (Eversole and Rizoiu, 1995). Histopathologic studies in animals and humans have shown that pulpal tissues underlying deep cavity preparations made with an erbium laser do not undergo pathological changes. It was shown, utilising rats teeth, that fibroblast proliferation is observed sooner and more frequently in the specimens treated with the erbium:YAG laser than those prepared with the high-speed drill (Takamori, 2000).
Also, Rizoiu et al (1996) found that the laser powered Er:Cr:YSGG, when used for preparation of carious lesions, had ‘no apparent adverse thermal effect as measured in the pulp space’ (Keller and Hibst, 1997).

Coluzzi (2000) states that ‘…laboratory studies indicate that the pulpal temperature of the treated tooth may actually decrease by five 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 vapourisation of the water. A high steam pressure then leads to microexplosions with erupting particles with a crater corresponding morphology.

‘Because the tissue is not vapourised 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.’ (Miserendino and Pick 1995)

**Precision of the erbium laser in cutting tooth structure**

Keller (1997) 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. Previously placed dental sealants can also be removed with the laser. Dental restorative preparations are possible and while 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 materials (Coluzzi, 2000) (Figure 2).

**Comfort of the patient: handpiece vs. erbium laser**

The non-contact laser preparation seems to be comfortable to the patients, whereas drilling may cause pain sensations due to various causes such as vibration, pressure, heat, and noise. In an article by Hadley et al (2000), intra-operative discomfort levels indicated a higher prevalence of discomfort among the air turbine/bur-treated teeth than among the erbium laser treated teeth.

Keller and Hibst (1997) 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 this 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 caries, only minimal discomfort was reported. In a second study, the pain of the laser versus mechanical drilling was compared. Only 6% of the patients required local
anaesthesia with laser preparation, compared to 11% of the patients with drilled cavity preparations. 83% of the patients indicated that the bur was more uncomfortable than the laser; 88% of the patients indicated a preference of the Erbium:YAG laser. ‘The pain perception during laser treatment was reduced; the pain was described as only like short needle sticks.’ (Miserendino and Pick, 1995)

Other effects of the laser on the tooth

Caries prevention

Hicks (1993) 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 four times more resistant to acid dissolution. The increase in resistance caused a significant reduction in the depth of the carious lesion. Theorising, the enamel micropores may trap the ions released (calcium, phosphate, fluoride) that become dissolved during the formation of caries. Enamel that has been lased has a greater attraction for the calcium phosphate and fluoride ions, with the result of a reprecipitation of the mineral phase. Therefore, irradiation by laser may be important in caries prevention in enamel that is sound.

Histologic effects

Effects observed by both the lased and the control groups showed no significant differences in the quantitative effects on the odontoblasts, predentine, and dentine, which showed mild changes in both groups. When the conventional drill was used, the histologic variations were larger for the pulpal tissue, odontoblasts, and predentine. 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 the author that the dental drill may be more harmful to the tooth than the erbium laser. The localised areas of healing seen within the pulp adjacent to the cavity preparations should be considered a normal physiological response. There was no significant damage to the pulp on histological examination of 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.’ (Convissar, 2000) (Figure 4)

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 (1997) (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 carbonisation occurs.

Two days post-operatively, the wounds are closed in the epithelial parts. Eight days post-operatively, the epithelial would 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 scalps. In contrast, the carbon dioxide laser cuts show a delay in wound healing of two to three days because of the extended thermal damage zones (Miserendino and Pick, 1995).

References


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