REVIEW ARTICLE

Applications of Lasers in Dentistry: A Review

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ABSTRACT
Lasers were introduced into the field of clinical dentistry with the hope of overcoming some of the drawbacks posed by the conventional methods of dental procedures. Since its first experiment for dental application in the 1960s, the use of laser has increased rapidly in the last couple of decades. At present, wide varieties of procedures are carried out using lasers. The aim of this review is to describe the application of lasers in dental hard tissue procedures. Lasers are found to be effective in cavity preparation, caries removal, restoration removal, etching, and treatment of dentinal sensitivity, caries prevention and bleaching. Based on development in adhesive dentistry and the propagation of minimum intervention principles, lasers may revolutionize cavity design and preparation.

Key words: laser, dental hard tissue, adhesive dentistry

INTRODUCTION

The use of lasers in dentistry has increased over the past few years. The first laser was introduced into the fields of medicine and dentistry during the 1960s (Goldman *et al*., 1964). Since then, this science has progressed rapidly. Because of their many advantages, lasers are indicated for a wide variety of procedures (Frentzen and Koort, 1990; Aoki *et al*., 1994; Pelagalli *et al*., 1997; Walsh, 2003). Conventional methods of cavity preparation with low- and high-speed handpieces involve noise, uncomfortable vibrations and stress for patients. Although pain may be reduced by local anaesthesia, fear of the needle and of noise and vibration of mechanical preparation remains causes of discomfort. These disadvantages have led to a search for new techniques as potential alternatives for dental hard tissue removal. The aim of this review is to describe the application of lasers in dental hard tissue procedures.

Historical development

The first experiment with lasers in dentistry was reported in a study about the effects of a pulsed ruby laser on human caries (Goldman *et al*, 1964). The results of that study showed that the effects varied from small 2-mm deep holes to complete disappearance of the carious tissue, with some whitening of the surrounding rim of enamel, indicating extensive destruction of carious areas along with crater formation and melting of dentine. Further work in the 1970's focused on the effects of neodymium (Nd) and carbon dioxide (CO_2) lasers on dental hard tissues. Early researches found that CO_2 lasers produced cracking and disruption of enamel rods, incineration of dentinal tubule contents, excessive loss of tooth structure, carbonisation and fissuring and increased mineralization caused by the removal of organic contents (Gimbel, 2000). It was also reported that the use of the CO_2 laser was unfavourable because of the loss of the odontoblastic layer (Wigdor *et al*., 1993).

Therefore, it was concluded that, unless heat-related structural changes and damage to dentinal tissues could be reduced, laser technology could not replace the conventional dental drill. Further advances in laser technology however, have identified acceptable biologic interactions. For example, the Er: YAG laser was tested for its ability to ablate (or vapourise) dental hard tissues (Gimbel, 2000). Enamel and dentine cavities were successfully prepared using the Er: YAG laser. Since then, this laser has been used for caries removal and cavity preparation, soft tissue minor surgery and scaling (Aoki and Watanabe *et al*., 1998).

CLINICAL APPLICATIONS

Cavity preparation

The Er: YAG laser was tested for preparing dental hard tissues for the first time in 1988. It was successfully used to prepare holes in enamel and dentine with low '*fluences*' (energy (mJ)/unit area (cm^2)). Even without water-cooling (Burkes *et al*., 1992), the prepared cavities showed no cracks and low or no charring while the mean temperature rise of the pulp cavity was about 4.3°C (Rechmann *et al*., 1998). In 1989, it was demonstrated that the Er: YAG laser produced cavities in enamel and dentine without major adverse side effects. The ablation efficiency was about one order of magnitude lower than for soft tissue. It was then concluded that dentine and enamel removal was very effective with no risk to the pulp (Armengol, 2000; Cavalcanti, 2003) and the ablation rates in enamel were stated to be in the range of 20-50 μm/pulse, and in dentine they were reported to be as high at lower fluences.

Clinically, cavity preparation in enamel results in ablation craters with a white chalky appearance on the surface of the crater (Tokonabe *et al*., 1999). In dentine, cavity margins are sharp and dentinal tubules remain open without a smear layer. In a clinical study conducted to evaluate the efficiency and safety of the Er: YAG laser for caries removal and cavity preparation in dentine and enamel (Cozean *et al*, 1997), Class I, II, III, IV and V cavities were prepared for amalgam and composite restorations. It was found that the Er: YAG laser was equivalent to the air rotor in its ability to make cavity preparations in enamel and dentine and remove caries. However, the floor of the preparation was not as smooth as that achieved with the high-speed drill.

Caries removal

Carious material contains a higher water content compared with surrounding healthy dental hard tissues. Consequently, the ablation efficiency of caries is greater than for healthy tissues. There is a possible selectivity in the removal of carious material using the Er: YAG laser because of the different energy requirement to ablate carious and sound tissues leaving those healthy tissues minimally affected. However, Rechmann *et al*. (1998) found that selective ablation of carious dentine is difficult with the Er: YAG laser. The ablation thresholds of healthy dentine and carious dentine are different. The ablation threshold of healthy dentine is two times higher than the corresponding threshold of carious dentine.

Therefore, very small fluences (energy (Joules) / area (cm^2)) of the Er: YAG laser energy are required to selectively ablate carious dentine. This low fluence will result in low efficiency of the ablation process (Shigetani, 2002). In another *in vitro* study investigating the effectiveness of caries removal by Er: YAG laser, it was found that the Er: YAG laser ablated carious dentine effectively with minimal thermal damage to the surrounding intact dentine (Aoki and Ishikawa *et al*., 1998). The laser removed infected and softened carious dentine to the same degree as the bur treatment. In addition, a lower degree of vibration was noted with the Er: YAG laser treatment. However, the study did not address the issue of selective removal of carious tissue and further studies of caries removal using lasers are indicated.

Restoration removal

The Er: YAG laser is capable of removing cement, composite resin and glass ionomer (Dostalova *et al*., 1998; Gimbel, 2000). The efficiency of ablation is comparable to that of enamel and dentine. Lasers should not be used to ablate amalgam restorations however, because of potential release of mercury vapour. The Er: YAG laser is incapable of removing gold crowns, cast restorations and ceramic materials because of the low absorption of these materials and reflection of the laser light (Keller *et al*., 1998). These limitations highlight the need for adequate operator training in the use of lasers.

Etching

Laser etching has been evaluated as an alternative to acid etching of enamel and dentine. The Er: YAG laser produces micro-explosions during hard tissue ablation that result in microscopic and macroscopic irregularities. These micro-irregularities make the enamel surface micro-retentive and may offer a mechanism of adhesion without acid-etching. However, it has been shown that adhesion to dental hard tissues after Er: YAG laser etching is inferior to that obtained after conventional acid etching (Martinez-Insua *et al*., 2000). These authors attributed the weaker bond strength of the composite to laser-etched enamel and dentine to the presence of subsurface fissuring after laser radiation. This fissuring is not seen in conventional etched surfaces. The subsurface fissuring contributed to the high prevalence of cohesive tooth fractures in bonding of both laser-etched enamel and dentine.

A similar conclusion was drawn from a study that compared shear bond strength (SBS) of composite resin to dentine surfaces following different treatments (Ceballos *et al*., 2001). These authors reported that acid etched specimens achieved the highest SBS values, while laser treatment showed the lowest SBS results. These findings suggest that extensive fissuring caused by laser treatment and the consequent poor bonding strength may outweigh the putative advantages of laser etching.

Treatment of dentinal hypersensitivity

Dentinal hypersensitivity is one of the most common complaints in dental clinical practice. Various treatment modalities such as the application of concentrated fluoride to seal the exposed dentinal tubules have been tested to treat the condition. However, the success rate can be greatly improved by the ongoing evaluation of lasers in hard tissue applications. A comparison of the desensitising effects of an Er: YAG laser with those of a conventional desensitising system on cervically exposed hypersensitive dentine (Schwarz *et al*., 2002) showed that desensitising of hypersensitive dentine with an Er: YAG laser is effective, and the maintenance of a positive result is more prolonged than with other agents.

Caries prevention

Several studies examined the possibility of using laser to prevent caries (Hossain *et al*., 2000; Apel *et al*., 2003). It is believed that laser irradiation of dental hard tissues modifies the calcium to phosphate ratio, reduces the carbonate to phosphorous ratio, and leads to the formation of more stable and less acid soluble compounds, reducing susceptibility to acid attack and caries. Laboratory studies have indicated that enamel surfaces exposed to laser irradiation are more acid resistant than non-laser treated surfaces (Watanabe *et al*., 2001; Arimoto *et al*., 2001).

The degree of protection against caries progression provided by the one-time initial laser treatment was reported to be comparable to daily fluoride treatment by a fluoride dentifrice (Featherstone, 2000). The threshold pH for enamel dissolution was reportedly lowered from 5.5 to 4.8 and the hard tooth structure was four times more resistance to acid dissolution. However, the actual mechanism of acid resistance by laser irradiation is still unclear and studies, particularly *in vivo*, to test those claims are required.

Bleaching

The objective of laser bleaching is to achieve an effective power bleaching process using the most efficient energy source, while avoiding any adverse effects (Sun, 2000). Power bleaching has its origin in the use of high-intensity light to raise the temperature of hydrogen peroxide, accelerating the chemical process of bleaching. The FDA approved standards for tooth whitening has cleared three dental laser wavelengths: argon, CO_2 and the most recent 980-nm GaAIAs diode. There are no reports at present about the use of the Er: YAG laser in bleaching techniques. The wavelength of the Er: YAG laser may be unsuitable for the procedures, but it is a further area that could be explored.

CONCLUSION

The Er: YAG laser has been found to have applications in areas such as cavity preparation, removal of caries and restorations, and etching of enamel. However, the advantages as well as limitations of the Er: YAG laser treatments have not yet been fully documented. There appear to be windows of opportunity for the Er: YAG laser in a range of dental applications. Lasers may revolutionise cavity design and preparation based on development in adhesive dentistry.

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