Use of the Er,Cr:YSGG and Er:YAG lasers in restorative dentistry

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_The Er,Cr:YSGG laser has an active medium of yttrium-scandium-gallium-garnet doped with erbium and chromium ions and emits free-running pulsed laser energy at a wavelength of 2,780 nm. the Er:YAG laser has an active medium of yttrium-aluminium-garnet doped with erbium ions and emits free-running pulsed laser energy at a wavelength of 2,940 nm. These wavelengths have a high absorption in water, which makes their application appropriate when ablating oral soft tissue or dental hard tissue. This article examines the principles of use for the Er:YAG and Er,Cr:YSGG lasers in clinical restorative dentistry and reviews the literature regarding different aspects of the use of laser energy on hard tissues.

_Introduction

In 1989, Keller and Hibst illustrated the potential of the Er:YAG laser (2.94 µm wavelength) for the effective ablation of dental hard tissues.[1] As a result there was new development and marketing of free-running, mid-infra-red wavelength lasers during the 1990's. These advantages permitted to address laser wavelengths that were complementary to target tissue elements, allowing clinically-significant ablation rates that did not cause pulpal or collateral thermal injury using proper energy levels. The erbium chromium YSGG (2,780 nm) and the erbium YAG (2,940 nm) laser wavelengths are well absorbed by water and hydroxyapatite contained at different component rates in hard tissue and appeared to offer safe use in cavity preparation.[2–4] The vaporization of interstitial water provided by the Er,Cr:YSGG and Er:YAG lasers results in an explosive dislocation of target hard tissue. These laser wavelengths offer several advantages for restorative dentistry, including precision, selective ablation of target hard tissue and carious lesions, less conductive thermal stimulation of the pulp, reduced collateral damage that might result from rotary instrumentation (such as tactile and thermal damage), and so forth.

This article examines the principles for using the Er,Cr:YSGG and Er:YAG lasers in clinical restorative


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dentistry and reviews the literature concerning different aspects of laser energy on hard tissues.

_Basic considerations

Using a laser requires delivering light energy of sufficient value to effect tissue change without causing unwanted collateral thermal damage by conducting excess heat into the surrounding tissues.[5] To do this it is essential to establish a rate of interaction that is commensurate with a time frame that allows such interaction to be clinically acceptable in terms of total time required for each procedure.

The rate and the speed of dental hard tissue ablation depends on the appropriate laser energy, in addition to the wavelength, pulse duration, pulse shape, repetition rate, power density, thermal relaxation time of the tissue, and delivery mode.[6-8]

The speed of ablation is also affected by the fluoridation of the tissue, the presence of ablation products and the incident angle of the delivery tip relative to the tooth: placing the delivery tip parallel to the axis of the enamel prisms, in order to access the interprismatic, higher-water content structure maximises the speed of ablation. Ablation is more efficient and heat transfer is minimized when the pulse width is reduced and peak power values rise.[9-11] In addition the use of sharp curettes to remove gross caries can reduce laser use to an acceptable timeframe. The depth of laser ablation depends on the parameters utilized, principally on the energy used per pulse and the number of pulses delivered. To avoid and prevent cracks or structural modifications, the tip (where present) must not touch the surface, nor should excessive energy be applied. When relatively high fluences are involved, it is possible that the laser light is absorbed by the mineral, which results in ablation and/or disruption of the mineral with some structural modification.[12-14] Many conflicting factors interfere with the recommended power value for laser-assisted ablation of dental hard tissue .The ablation threshold of human enamel has been reported to be in the range of 12–20 Joules/cm^2 and for dentin, 8–14 Joules/cm^2 for the Er:YAG and Er,Cr:YSGG laser wavelengths. For an average laser delivery spot-size, using a free-running pulsed emission mode, this may equate to approximately 150–250 mJ/pulse.

It is recommended that the clinician follow manufacturer's guidelines in establishing laser treatment protocols for a given laser, keeping in mind the differing operating parameters of air/water/spot size and any power losses that may occur within differing delivery systems.

_Use of co-axial water spray

The use of water spray with mid-infrared lasers allows working on hard tissues with thermal increases of less than 5 °C: it is essential to prevent debris from accumulating at the bottom of the cavity, which can lead to conductive heat damage.[15-16]

The effects of excessive incident power, the build-up of ablation products, which cause thermal damage to the target and surrounding tissue and the removal of such products by means of a co-axial water spray have been discussed in the literature.[17-21] The affinity of mid-infrared laser wavelengths with water contained in the tissue allows for selective ablation,

in which greater absorption takes place in demineralised tissue, which is richer in organic material and has a higher percentage of water. This absorption offers some protection to the sound underlying tissue while reducing penetration from the beam. To prevent build-up, ablation products should be removed by means of a co-axial water spray. If water spray is not used, laser light is then absorbed by the mineral and the hydroxyapatite crystal themselves may be heated above their melting point.

In consequence, either some disruption of the crystal structure occurs with subsequent resolidification in a different form, or direct ablation of the mineral occurs, but there also is conductive heat transfer to interstitial free water. Relatively high fluences are needed at these wavelengths for this transfer of heat to occur. A micro-cavitated surface that may enhance retention of composite resin can be achieved by using Er,Cr:YSGG or Er:YAG lasers to irradiate enamel and dentin but water spray must be utilized. Conversely, the absence of water spray can lead to cracks in enamel or melted dentin, resulting in unsubstained enamel prisms and flat adhesion dentin surfaces with closed tubules. The negative effects could lead to marginal leakage and non-adhesion of the composite material.

_Exceptions to using water spray

There are two clinical situations which can be treated with lasers without the simultaneous use of a co-axial water spray: the desensitizing technique and the pulp capping. The desensitizing technique must be done without water and without the laser tip making direct contact with the tooth. In addition the laser should be used for a short time only and with low power (few pps, very long releasing time, few mJ). For the pulp capping the technique must be carried out without water but with air cooling and the tip must touch the surface for only a few seconds.

_Cavity margin considerations

A succession of studies has identified the fragility of laser-irradiated enamel, relative to the stability of the post-restoration margins. Studies have proposed a combined approach of combined laser-irradiation, acid-etch techniques, to overcome such potential problems. It may be necessary to remove grossly overhanging and unsupported enamel with a rotary bur, scalpels or an ultrasonic device either to expedite cavity preparation or provide a stable post-restoration margin.[22-27]

_Acid-etch considerations

Er:YAG laser irradiation produces a surface visually similar to an acid-etch pattern but without a smear layer. While the surface produced by the Er:YAG laser is similar to the conventionally prepared, etched enamel surface, it still requires acid etching to obtain an equivalent bond strength. The use of acid etching for enamel and dentin surface modification is must be carried out each time before bonding application. Laser irradiation of enamel is not a valid alternative to acid-etching pretreatment for resin composite materials adhesion. As a result, Er,Cr:YSGG and Er,YAG irradiation alone cannot be recommended as a viable alternative to acid etching.[28,29]

_Avoidance of dehydration

Before bonding application the dentin surface must not be dehydrated: the use of lasers without water—mist before composite restorations is no longer recommended. Laser ablation does not produce a smear layer, which would impede adhesion to laser-irradiated surfaces. Nevertheless, a selective ablation of organic tissue occurs when these lasers are uses; as a result, there is less collagen left to be exposed or hybridised after laser conditioning of dentin, indicating that acid-etching and water spray after laser treatment is advisable.[30,31]

_Choice of composite restorative materials

The choice of composite materials must be made on the basis of the depth and width of dentin craters. The laser irradiation of enamel and dentin by Er,Cr:YSGG or Er:YAG lasers results in a "super-rough", micro-cavitated surface that may predispose to ideal retention of composite resin but it is necessary to remember this difference from laser to bur in the choice of materials. The


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use of composite nano or micro-filled is fundamental to properly restore laser ablated cavities. Whenever possible, it is advisable to first use a layer of flowable composite. The seal at enamel margins in Er,Cr:YSGG and Er:YAG lased cavities depends on the resin composite formulation of the corresponding adhesive.[32,33]

_Isolation and safety considerations

A rubber dam isolation technique must be used in every procedure to maintain decontamination provided by the laser. Safety measures should include the use of specific protection glasses for the doctor, the assistant and patient, the use of appropriate face-masks to avoid plume aspiration, high-speed aspiration of plume and debris. In addition the dentist must use non-reflecting instruments. Magnification is recommended to allow the dentist better control of his or her work.

_Summary

The Er,Cr:YSGG laser has an active medium of yttrium-scandium-gallium-garnet doped with erbium and chromium ions and emits free-running pulsed laser energy at a wavelength of 2,780 nm. The Er:YAG laser has an active medium of yttrium-aluminium-garnet doped with erbium ions and emits free-running pulsed laser energy at a wavelength of 2,940 nm. These wavelengths have a high absorption in water, which makes their application appropriate when ablating oral soft tissue as well as dental hard tissue. Advantages of using these laser wavelengths in restorative dentistry include precision, selective ablation of target hard tissue and carious lesions, reduced collateral damage that might be caused by rotary instrumentation (tactile and thermal damage), less conductive thermal stimulation of the pulp, no vibrations, and so forth. However, it is essential to apply knowledge and accepted laser settings and modes of application and also to follow the clinical aspects and rules to obtain the best results. Using these lasers and co-axial water spray simultaneously is always advisable, with the two clinical exceptions of the desensitising technique and pulp capping. Other main points to consider are the cavity margins that need to be finished, the use of acid after laser treatment that permits the best adhesion, and the choice of composite materials, which must be based on the surfaces produced by the laser treatment. Specific safety is necessary when using these devices._

_References

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Editorial note: The whole literature list can be requested from the author.

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