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Dental laser drilling: Achieving optimum ablation with the latest generation Fidelis laser systems

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INTRODUCTION

The erbium (Er:YAG) laser has been recognized as the dental laser of choice for effective, precise and minimally-invasive ablation of hard dental tissues. Of all infrared lasers, the erbium laser wavelength of 2.94 μm has the highest absorption in water and hydroxyapatite (see Fig. 1) and is thus optimal for cold 'optical drilling' of enamel, dentin and composite fillings.

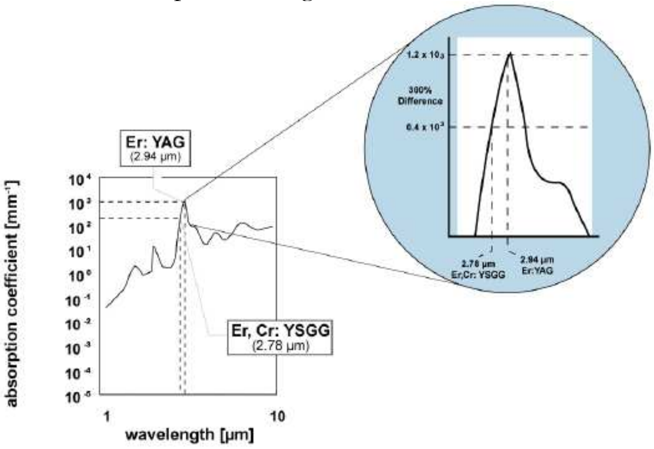

Fig.1: The Er:YAG (2.94 μm) laser has the highest absorption in water and hydroxiapatite. An alterantive laser that emits in the 3 μm region is the Er:YSGG (2.78 μm) laser, however this laser has a 300% lower absorption and is thus less suitable for laser drilling.

The early standard-technology erbium dental lasers failed to gain wide acceptance by the dental community because their optical drilling speeds were slower in comparison to the mechanical bur. This changed with the introduction of the Fidelis dental lasers[1] with the Variable Square Pulse (VSP) technology they incorporate.[2] VSP provides very short, almost square-shaped erbium laser pulses of adjustable duration. Tests have shown that the ablation speed of the VSP-technology based Er:YAG lasers is comparable to those obtained by classical means.

The most recent technological breakthroughs that have been incorporated into the latest generation of Fidelis dental lasers (Fidelis Plus III and Fidelis Er III)[3] are: SSP (Super Short Pulse) mode[4] for extremely fine and minimally-invasive laser ablation; and MAX mode for maximum optical drilling speeds - even faster that those obtained by mechanical burs. With these two additional modes, dental lasers have finally achieved their original goal: to replace mechanical drills with more precise and less-invasive optical technology without sacrificing either ease-of-use or operating speed.

SCIENTIFIC PRINCIPLES

Exciting developments in the theoretical understanding of the laser ablation of biological tissues[5] have facilitated recent rapid technological advances in laser dentistry.

It is now well understood that there are four ablation regimes (see Fig. 2), defined by the relationship between the laser pulse duration and the laser pulse energy (or more correctly, laser fluence, i.e. the laser energy per surface area in J/cm²).

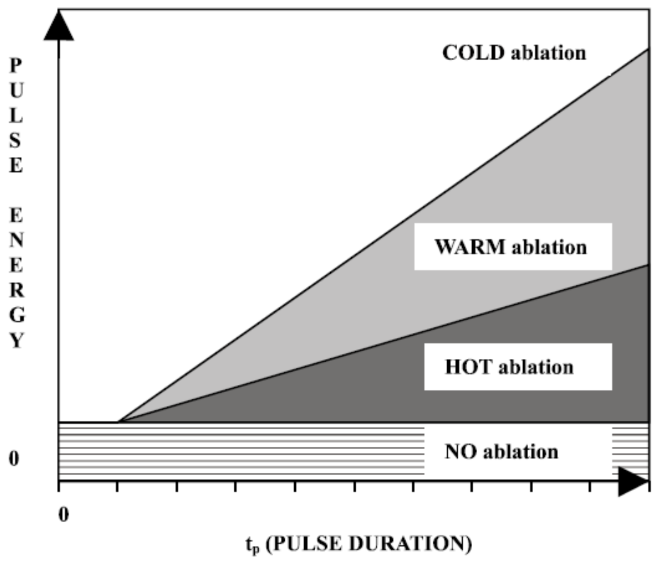

Fig.2: Schematic overview of the four ablation regimes.

At high energies and low pulse durations, the speed of ablation is faster than the rate of diffusion of heat into the tissue, so that all of the laser energy is used up in COLD ABLATION (See Fig. 3). With decreasing energies and/or longer pulse durations, the layer of tissue, that has been thermally-influenced by the time the pulse ends, becomes thicker. Thermal effects become more pronounced and, with these, ablation efficiency is considerably reduced (WARM ABLATION and, at even lower energies, HOT ABLATION). At energies below the ablation threshold there is NO ABLATION and all the energy is released in the form of heat, independent of the laser pulse duration.

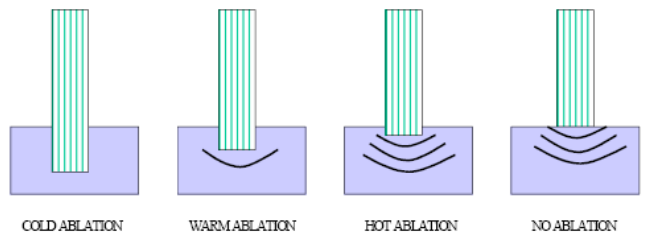

Fig.3: The effect of the laser beam on hard dental tissue in the four ablation regimes.

Many practitioners might assume that, in order to work more safely, laser energy should be decreased. Paradoxically this is not the case. Indeed the opposite is true. For a given pulse duration, if the operator reduces the energy of the laser, he may achieve precisely the opposite result, i.e. more thermal effects in the tissue.

THE LATEST GENERATION FIDELIS LASER MODES

The latest generation Fidelis lasers enable the operator to select from the following modes:
SSP (Super Short Pulse: 50 µsec), VSP (Very Short Pulse: 120 µsec), SP (Short Pulse: 300 µsec), LP (Long Pulse: 600 µsec), VLP (Very Long Pulse: 1000 µsec).

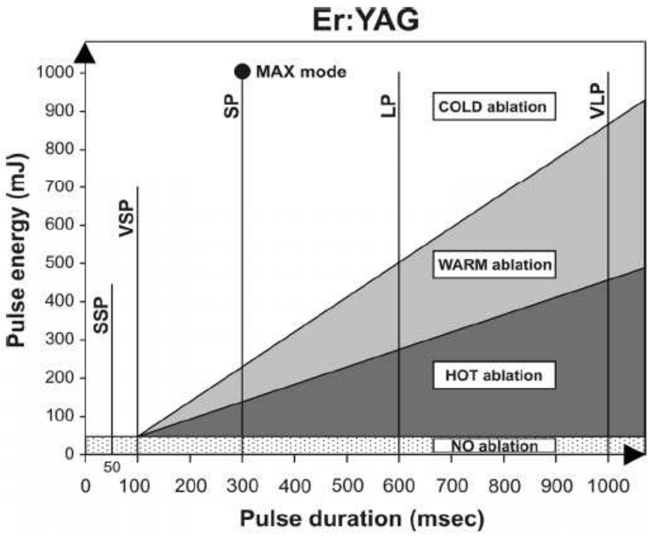

Fig.4: Cold and hot regimes for Fidelis Er:YAG lasers.

The SSP pulse durations are extremely short (approximately 50 µsec) which is below the 100 µsec Tissue Relaxation Time for enamel. The SSP pulses are therefore best suited for precise and fine ablation at low laser energies. For standard work, VSP pulses are recommended. And for maximum speed of ablation, MAX mode is most suitable, since, by fixing the laser energy and pulse duration to the optimal high values, MAX Mode can ensure cold ablation. The LP and VLP modes are best suited to soft tissue applications where thermal coagulation effects are desirable.

COMPARISON OF Er:YAG WITH Er:YSGG

Since the absorption coefficient of Er:YSGG laser is three times smaller than that of the Er:YAG laser, the range of safe parameters that can be used is considerably reduced when using an Er:YSGG source. Firstly, the ablation threshold energy is three times higher. Secondly, in order to achieve cold ablation, three times higher fluences are required. This is particularly difficult to achieve with fiber delivery systems, since they cannot deliver high energies and/or high intensities because of their high absorption and low damage threshold. For this reason, most Er:YSGG lasers operate with considerably lower ablation efficiency and closer to or within the warm/hot ablation regimes.

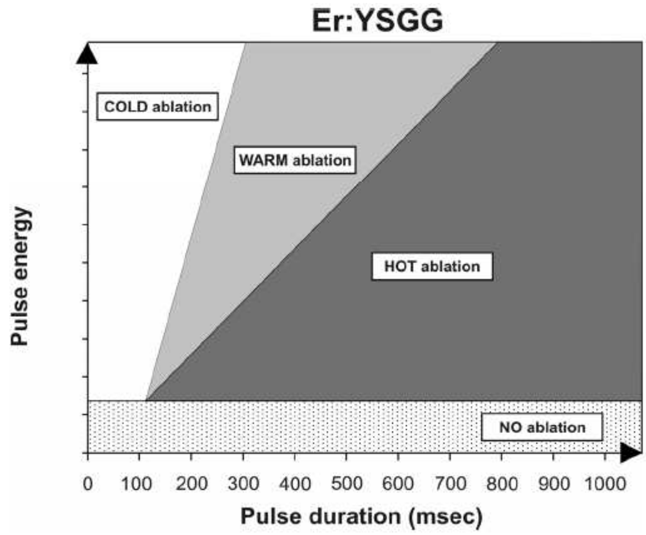

Fig.5: Cold and hot regimes for Er:YSGG lasers.

CONCLUSIONS

For precise, hard-tissue laser procedures, erbium lasers offer the safest and most efficient solutions. Careful control of the pulsewidths enables the nature of the ablation to be controlled.

Of the different erbium laser technologies, Er:YAG has the optimum absorption characteristics for hard tissue procedures, with cold ablation possible using far lower energy values, and thus greater safety.

The latest generation of Fidelis laser systems from Fotona utilize an Er:YAG laser source, delivered using precise VSP control of the pulsewidth. This enables a range of laser drilling techniques including very fine, precise "cold" ablation and MAX mode, enabling the fastest, most efficient hard tissue ablation available.

The two new modes, SSP and MAX, mean that dental lasers have finally achieved their original goal: replacing mechanical drills with more-precise and less-invasive optical technology, without sacrificing safety, ease of use or operating speed.

REFERENCES

1. Variable Square Pulse Technology is a proprietary technology of Fotona (www.fotona.com).
2. Fidelis™ denotes a family of dental laser systems developed and manufactured by Fotona. (www.fotona.com).
3. Fidelis Plus II (Er:YAG 2.94 μm and Nd:YAG 1.06 μm combined laser system) and Fidelis Er II (Er:YAG 2.94 μm laser system) are the latest products developed and manufactured by Fotona (www.fotona.com).
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