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

Matjaz Lukac, (Research Associate, Institute Jozef Stefan, Ljubljana, Slovenia)
Marko Marincek,(Research Associate, Institute Jozef Stefan, Ljubljana, Slovenia)
Ladislav Grad,(Research Associate, Faculty of Mechanical Engineering, Ljubljana, Slovenia)

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.

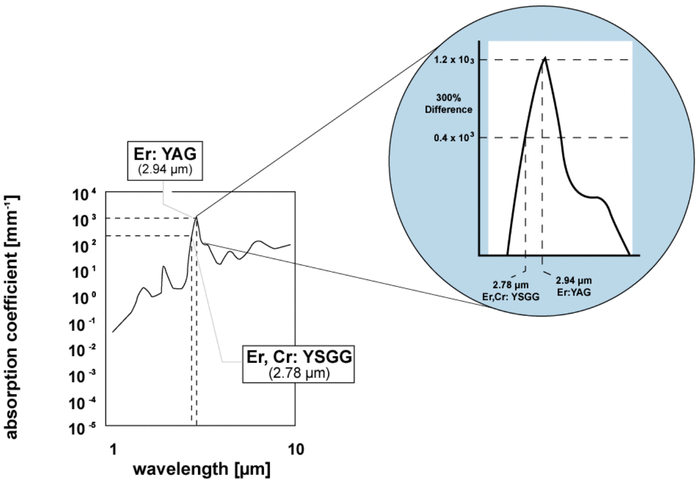

Fig.1: The Er:YAG (2.94 μm) laser has the highest absorption in water and hydroxyapatite. An alternative laser that emits in the 3 μm region is the Er:YSGG (2.78 μm) laser, however this laser has a 300% lower absorption and is thus less suitable for laser drilling.

The early standard technology erbium dental lasers failed to gain wide acceptance by the dental community because their optical drilling speeds were slower compared to the mechanical bur. This changed with the introduction of the Fidelis dental lasers[1] with the VSP (Variable Square Pulse) technology they incorporated.[2] VSP provides very short, almost square pulse-shaped erbium laser pulses of adjustable pulse 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 latest technological breakthroughs that have been incorporated into the second generation of Fidelis dental lasers (Fidelis Plus II and Fidelis Er II)[3] are: the SSP (Super Short Pulse) mode[4] for extremely fine and minimally invasive laser ablation; and the MAX mode for maximum optical drilling speeds - 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 ease of use and operating speed.

SCIENTIFIC PRINCIPLES

Recent rapid technological advances in laser dentistry have been facilitated by equally exciting developments in the theoretical understanding of laser ablation of biological tissues.[5]

It is now well understood that depending on 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) there are four ablation regimes (see Fig. 2). The more energy that becomes heat, the less efficient the ablation becomes and the greater discomfort and pain the patient experiences.

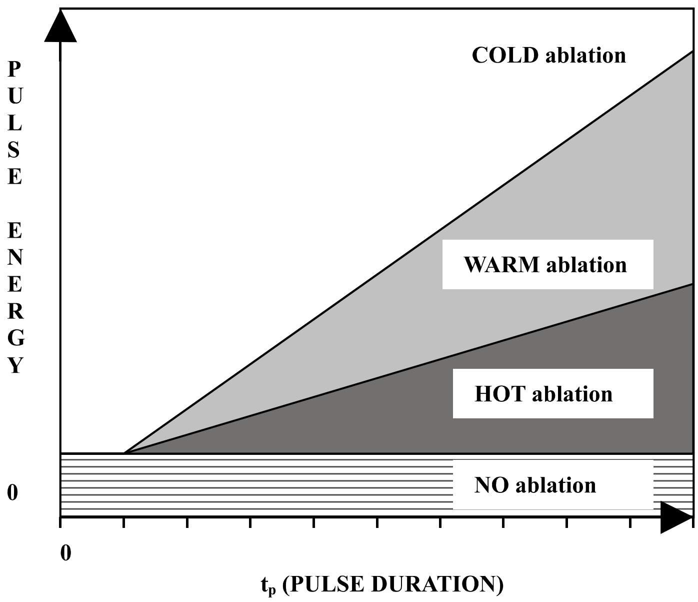

Fig 2: Schematical overview of the four ablation regimes

At high energies and low pulse durations, the speed of ablation is faster than the diffusion of heat into the tissue so that all of the laser energy is used up for COLD ABLATION (See Fig. 3). With decreasing energies and/or longer pulse durations, the thermally influenced layer of tissue by the end of the pulse 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.

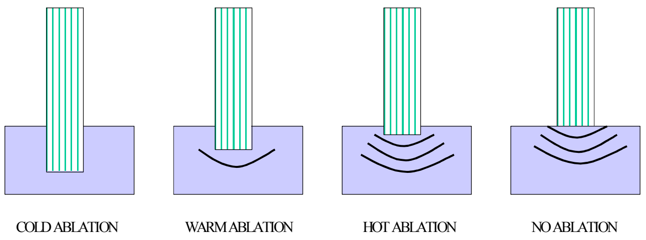

Fig.3: The effect of the laser beam on hard dental tissue in the four ablation regimes. The ablation efficiency is highest and thermal effects lowest in the cold ablation regime. When the laser energy is too low there is no ablation and all of the energy is released in the form of heat.

Many practitioners may assume that in order to work more safely laser energy should be decreased. Paradoxically this is not the case. Indeed the opposite is true. 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 SECOND GENERATION FIDELIS LASER MODES

The second generation Fidelis lasers enable the operator to select among 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).

The SSP pulse durations are extremely short, approximately 50 µsec which is bellow the 100 µsec tissue relaxation time. The SSP pulses are therefore best suited for precise and fine ablation at low laser energies. For standard work VSP pulses are recommended. For maximum ablating speed 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 used for soft tissue applications where thermal coagulation effects are desirable.

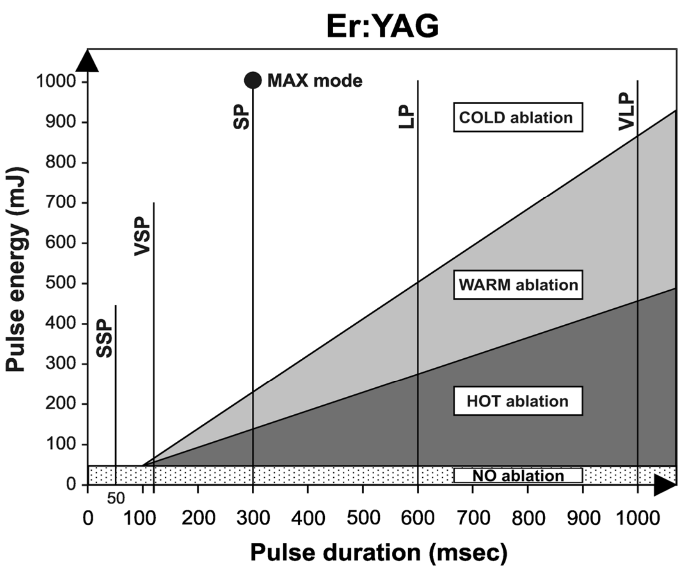

Fig.4: Cold and hot regimes for Fidelis Er:YAG lasers

COMPARISON OF Er:YAG WITH Er:YSGG

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

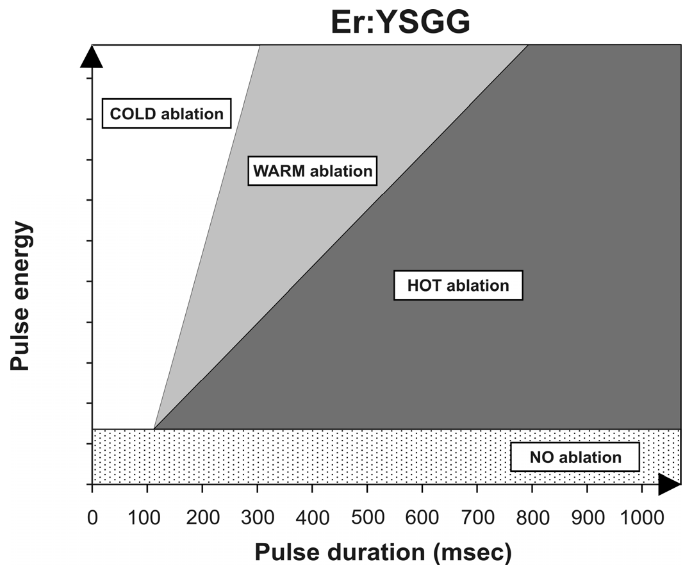

Fig 5: Cold and hot regimes for Er:YSGG

REFERENCES

1. Variable Square Pulse Technology is a proprietary technology of Fotona (www.fotona.si).
2. Fidelis™ denotes a family of dental laser systems developed and manufactured by Fotona. (www.fotona.si).
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.si).
4. M. Lukac, M. Marincek, L. Grad. Super VSP Er:YAG Pulses for Fast and Precise Cavity Preparation. J. Oral Laser Applications 2004;4:171-173.
5. B. Majaron, et al. Heat Diffusion and Debris Screening in Er:YAG Laser Ablation of Hard Biological Tissues. Appl. Phys. B 66,1-9 (1998).