

# New horizons for Er:YAG lasers: QSP mode advantages in the Lightwalker AT

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**Fig. 1** Group content. (Photos/ Provided by Evgeniy Mironov, DDS)



## Abstract

Lasers as a tool for everyday practice in dental medicine are becoming more popular since the 1992 invention of the Er:YAG wavelength for hard dental tissue preparation. Strong acceptance from patients, plus painless and easy operation are just some of the many advantages that usually influence the decision to add a laser in the clinic.<sup>1,2</sup> Today, requirements demanded by and expectations of the dental community to add a laser to the practice are much higher, and just being quieter than the high-speed drill and providing painless dentistry is not enough.

Dentists expect much more – to be able to do almost everything with one machine, to do procedures in less time and to be cost-effective. A very important step forward in dental lasers and specifically Er:YAG applications is the QSP (quantum square pulse) modality in the range of VSP (variable square pulse)

available in Fotona's Lightwalker AT hard- and soft-tissue laser (Technology4Medicine, San Clemente, Calif.). Based on simple physics, this mode allows dentists to work with finesse and control, even on higher energy and power settings, making all procedures faster compared with traditional Erbium laser pulsing modes, and even more painless. This in-vitro study researches the most suitable parameters for hard tissue preparation with the new QSP mode and compares it with the classic tools such as the high-speed drill, and the proven gold standard for Er:YAG laser enamel preparation, the MSP mode. Clinical cases from everyday practice are presented to illustrate a wide range of flexible and fast procedures that can be performed with the Er:YAG QSP pulse mode.

## Introduction

For 20 years erbium lasers have been on the dental market, and their main usage has been the preparation of the hard tissues, including enamel, dentine, caries lesions and bone. The widely used Er:YAG laser is well known for its strong absorption in water and hydroxylapatite, which gives it the ability for fast cutting and preparation speeds in these tissues with negligible thermal effects.<sup>5</sup> During past years, manufacturers have worked on improving their laser systems, researching more suitable parameters for optimizing the work on hard tissues. Even though the Er:YAG laser wavelength is well absorbed in dental tissues due to the high percentage of hydroxylapatite

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**Table 1** Results from the dye immersion test are given in percentages and number of teeth with coloration. The last column shows the most successful samples number in each group.

Change in a filling color	++	+	-	+	-
Penetration in tissue of MB	++	+	+	-	-
12Hz/500mJ QSP- 6W avg.	2/15 13,33%	2/15 13,33%	1/15 6,67%	2/15 13,33%	8/15 55,33%
15Hz/300mJ QSP-4,5W avg.	-	2/15 13,33%	-	1/15 6,67%	12/15 80%
15Hz/300mJ+ 10Hz/120mJ QSP-4,5+1,2W	-	1/15 6,67%	-	-	14/15 93,33%
30Hz/300mJ+ 10Hz/120mJ MSP – 9W avg.	-	1/15 6,67%	3/15 20%	-	11/15 73,33%
High speed drill – 19W	5/15 33,33%	-	4/15 26,67%	2/15 13,33%	4/15 26,67%

and water in the tooth structure, there have been some residual side effects affecting cutting ability. One is absorption of the laser energy in the debris cloud, which is formed after the ablation from the very first shot, thus reducing the useful energy for cold ablation of dental tissues. Scattering of the beam in the debris cloud can also lead to redirection of the beam from its original path and preparation margins are not well defined.<sup>3-5</sup>

Research led to the development of a pulse duration shorter than the time necessary to form a debris cloud (50 - 150 ms),<sup>3</sup> making the time between pulses longer than the debris cloud, ensuring there will be no absorption of the pulse energy. This is done by dividing one long pulse (for example 600 ms) into five super short pulses (50ms) increasing the herz-rate up to 120 Hz. This is possible because of physical properties of the Er:YAG atoms and Fotona's advanced and proprietary control of the laser pump source.

Another useful effect of dividing a pulse is that the QSP mode achieves five shorter pulses with the same energy but with significantly higher peak powers. This makes it possible to work with low energy but with high peak powers, higher precision and more speed compared with other hard-tissue pulsing modes for other lasers. Higher energy density and higher peak power ensures cold, effective ablation, resulting in less thermal damage and less pain.

### Materials and methods

Our team designed this study to find the best parameters for enamel preparation with the QSP mode and compare them with the proven and effective MSP mode and high-speed drills. Microleakage

tests and time-splitting were used to determine the preparation speed advantages.

The experiments were conducted on bovine teeth, freshly extracted and kept in saline solution before preparation. The teeth were extracted from cows raised on the same farm under the same conditions and diet. The donor animals varied in age, so we found three groups of teeth to work on – freshly erupted incisors, old incisors and premolars.

For the microleakage test we prepared cavities sized 3-by-3 mm on the lingual surface of the incisors and premolars until reaching the enamel-dentine junction. One hundred fifty teeth were divided into five groups – 15 in each group were tested for microleakage with methyleneblue and 15 for bacterial contamination with Lactobacillus.

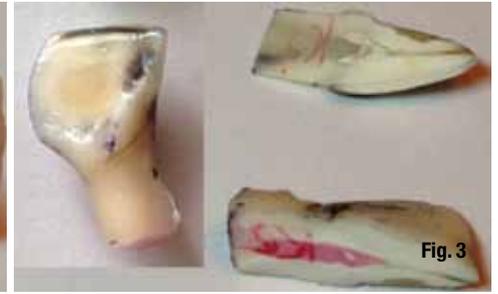
The first test group was treated with the QSP mode with 500mJ/12Hz, an average power of 6 watts to approximate the MSP average power for enamel preparation, which was the speed-determining parameter.

The second test group was treated with the QSP mode with 300mJ/15Hz, an average power of 4.5 watts. This is the same pulse energy for MSP enamel preparation from the factory presets.

The third test group was treated with the QSP mode with 300mJ/15Hz, an average power of 4.5 watts and subsequent surface modification procedure, QSP 120mJ/10Hz, the same as the MSP factory presets.

The first control group was treated with the MSP mode with 300mJ/30Hz, average power of 9 watts and subsequent surface modification procedure – MSP 120mJ/10Hz, the factory presets for enamel preparation and surface modification.

The second control group was treated with a high-speed drill, the Kavo GENTLEsilence 8000 LUX



**Fig. 2** 300mJ/15Hz with 120mJ/10Hz QSP without any leakage (-/-).

**Fig. 3** MSP 300mJ/30Hz and 120mJ/10 Hz control group specimen without any leakage (-/-).

**Fig. 4** High-speed drill control group sample with more than 1 mm penetration of dye in both directions (++/+++).

B, 19 watts output power, equipped with a Meisinger green-coded diamond bur. The burs were replaced with new burs for every 10 teeth.

Each group consisted of six premolars, six to seven freshly erupted incisors and 17 to 18 old incisors, divided in subgroups for coloration and Lactobacillus contamination tests with an equal number of three kinds of teeth in each (Fig. 1).

All teeth were prepared in one day, kept in saline and filled with GrandioSo (Voco, Germany) nano-hybrid light-cured composite and Futurabond M (Voco, Germany) one-bottle, self-etching, seventh-generation bonding agent. All roots were cut for retrograde pulp removal procedure. Pulp chambers of 75 teeth for methyleneblue coloration test were filled with additive-condensation silicone impression material, but those used designated for bacterial penetration testing were left hollow.

Teeth were thermocycled (50-55oC) with 5,000 cycles. After isolation with vanish, except 1 mm around the cavities, they were immersed in Methyleneblue for 48 hours. After longitudinal section at the middle of the filling on each tooth, microleakage was registered with light transition microscopy analysis. Leakage and coloration of more than 1 mm are given two pluses (++), while less than 1 mm receive one plus (+), considering coloration of the filling material and toward dentine.

## Results and conclusions

Results from the dye immersion test are given in Table 1 in percentages and number of teeth with coloration. The last column shows the most successful samples number in each group – without any microleakage in both filling materials and dental tissues. The best results showed QSP preparations done with 300mJ/15Hz and surface modification with QSP 120mJ/10Hz – 14 of 15 samples are without any leakage. The group with same parameters but without subsequent surface modification also demonstrated good results of 80 percent success rate.

### Analysis of microleakage test results:

1) Surface modification done with 10Hz/120mJ in QSP mode ensures perfect sealing of the cavity

and had to be performed with faster movements compared with the same procedure in MSP mode.

2) QSP preparation without subsequent lowering of the energy and repetition rate for etching also is ensuring adequate bond strength if the energy used was lower than 300mJ.

3) High-speed drill specimens showed results with much higher incidence of microleakage, only 26.67 percent without any leakage.

### Clinical aspects:

1) QSP mode preparations were much faster and also much quieter.

2) Using 12Hz/500mJ was too powerful and hard to control. To achieve deeper preparation it is recommended to switch to 15 Hz/160 to 300 mJ.

3) The surface modification regime was faster, so to perform efficient etching the handpiece needs to be moved faster.

## Time-split test

For the time-split test, four groups of 30 teeth (10 from each kind) are prepared with four modes, without using the surface modification procedure.

- 1) 500mJ/12 Hz QSP
- 2) 300mJ/15 Hz QSP
- 3) 300mJ/30 Hz MSP
- 4) High-speed drill

For this test we used a digital stopwatch operated by an assistant, starting on the first laser shot and stopping on command from the operator. The size of the cavities was 4-by-4 mm until reaching the

**Table 2\_** Average times in each mode.

Mode used / Tooth type	Old incisor	Freshly erupted incisor	Premolar
500mJ/12 Hz QSP	10,13 sec. avg.	14,08 sec. avg.	16,48 sec. avg.
300mJ/15 Hz QSP	11,09 sec. avg.	14,63 sec. avg.	19,96 sec. avg.
300mJ/30Hz MSP	11,92 sec. avg.	15,31 sec. avg.	21,33 sec. avg.
High speed Drill	12,84 sec. avg.	19,89 sec. avg.	24,90 sec. avg.

**Table 3\_** The time difference between different kinds of teeth in the same mode.

Mode/ difference between groups	Freshly erupted incisors to Old incisors	Premolars to Old incisors
500mJ/12Hz QSP	38,99% slower	62,68% slower
300mJ/15 Hz QSP	31,92% slower	79,98% slower
300mJ/30Hz MSP	28,43% slower	78,94% slower
High speed Drill	54,90% slower	93,92% slower

**Table 4\_** The time difference between different modes in the same kind of teeth.

	300mJ QSP To 500 mJ QSP	300mJ MSP to 500mj QSP	High speed Drill to 500 mJ QSP
Old Incisors	9,47% slower	17,67% slower	26,75% slower
Freshly erupted Incisors	3,90% slower	8,73% slower	41,26% slower
Premolars	21,11% slower	29,42% slower	51,09% slower

enamel-dentine junction on the lingual surface, thus ensuring that equal amount of enamel was removed and the only difference was due to enamel hardness.

Average times in each mode are given in Table 2.

Taking as a standard the fastest prepared teeth – i.e., old incisors – the time difference between different kinds of teeth in same mode is shown in Table 3. Also the time difference between different modes in the same kind of teeth can be calculated by using as a standard the fastest mode – 500mJ/12 Hz QSP – as shown in Table 4.

**\_Time-split test conclusions**

1) In harder enamel specimens (premolars), the time for preparation does not vary significantly in

QSP and MSP, while the high-speed drill was much slower (compared with old incisors).

2) There was a proportional slowing of the preparation speed according to the enamel hardness. This was an in-vitro test, and the results cannot be correlated to any kind of human dental-tissue preparation speed.

3) QSP 500 mJ/12 Hz is the fastest and, if we take it as a standard, calculation of the difference according to operation mode and types of teeth is possible.

4) The high-speed drill was slowest in all kinds of tissue.

5) Between MSP and QSP mode, there is significant difference only in the hardest teeth (premolars). The two modes are equally suitable for cavity preparation of enamel of average hardness.

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Fig. 5

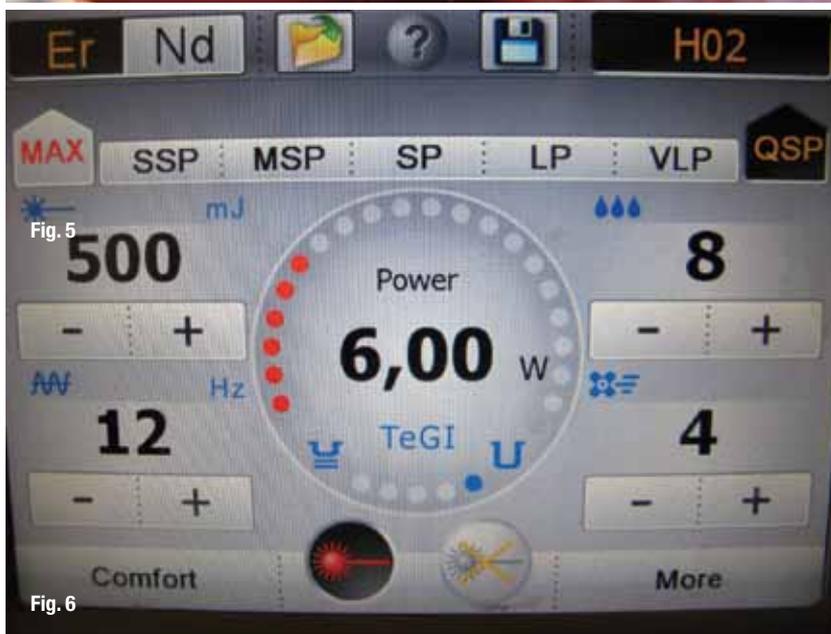


Fig. 5

Fig. 6



Fig. 7

Figs. 5-7\_The gum is unharmed even after marginal preparation with high energy.

## A clinical case

A clinical case is described to show the advantages of the QSP mode in everyday practice. The patient is a 23-year-old male with anxious reactions to dental procedures and is sensitive to cold in the lower right quadrant. After initial checkup we found a carious lesion on the cervical area on tooth #45 (European numbering system), appearing to be deep and acute with exposed dentine.

After injection, explanation of the laser function and possibilities, we started the cavity preparation with QSP mode and 500mJ/12 Hz, the highest possible average power with QSP and, as proved in the in-vitro test, the fastest regime. Working time was counted with a stopwatch, and after five seconds most of the decayed enamel and dentine were removed.

The gum is unharmed even after marginal preparation with such a high energy – this is a clinical evidence that in this mode the scattering and absorption effects in the debris cloud are negligible and allows fast and accurate preparation (Figs 5-7). In the deeper zone, we reduced the energy to 300mJ, but raised the repetition rate to 15Hz, thus being fast enough but still quiet.

After five seconds the whole cavity is cleared of carious dentine. After placing the haemostatic cord (#8, Pascal Co., USA), Calcimol LC (Voco, Germany) is used as a liner, covered with Grandioso Heavy Flow and finally filled with GrandioSo (Voco), using the Futurabond M (Voco) bonding system (seventh generation self-etching).

So fast preparation is possible in acute caries, there is proportional relation of the time needed for preparation and the water content of the target tissue, but this mode is very suitable in pediatric dentistry, where in most cases the working time is limited by the patient's tolerance (Figs. 8-10).

## Discussion

Real clinical benefits from new mode of quantum square pulse are easy to recognize. The margins of preparations for filling, or for surface modification are clearer and sharper than with any other working mode. This is important when working close to the pulp or near the gingiva. It is a safe operation mode in class II cavity preparation where the neighbor teeth should be kept untouched.

The parameters used in these cases are subject to change according to personal sensitivity and the type of target tissue, but biophysical constants guarantee the cold ablation regime such as power density, time of exposure and proper water supply should be closely observed. This requires a good working knowledge of the properties of light and

lasers and the ability to calculate parameters and make necessary changes by monitoring laser-tissue interaction.

Speed of preparation is especially important in pediatric dentistry and with anxious patients, and the QSP mode is the method of choice and does not sacrifice precision. The ability to quickly change pulse durations and repetition rates gives us the opportunity to work efficiently in different types of tissues with maximum safety.

**Conclusion**

This study demonstrates that an Er:YAG laser can offer significant advantages to standard treatment protocols.<sup>6</sup> Also, the QSP mode offers even more important advantages, adding additional treatment options. The laser is safe and effective, appealing to patients who are afraid of dentistry.

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Fig. 8



Fig. 9



Fig. 10

Figs. 8–10\_Fast preparation is possible in acute caries.

<b>_about the author</b>	<b>laser</b>
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