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Safety Evaluation of High Speed MAX mode Er:YAG Laser Cavity Preparations

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ABSTRACT

Early erbium and CO_2 lasers failed to gain wide acceptance in the dental community because their optical drilling speeds were slower in comparison to the mechanical bur. This has changed in the past few years; much faster ablation speeds are now possible and dental lasers with variable square pulse technology even exceed the drilling speeds of conventional burs. In this paper we report on a clinical study of the safety of the latest Er:YAG lasers, which operate in high speed MAX mode. Pulpal inflammatory response to cavity preparation on erupted caries and restoration-free third molars in need of extraction were analyzed. Teeth were bio-prepared and examined for the presence of an inflammatory response. The sensitivity of the patients following cavity preparation was also ranked and compared with the control group. The results show that the variable square pulse Er:YAG lasers operating in high speed MAX mode cause no permanent pulpal damage and can be safely used for fast cavity preparations.

Key words: Er:YAG, variable square pulse technology, MAX mode, ablation speed; cavity preparations.

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I. INTRODUCTION

Erbium: yttrium-aluminum garnet (Er:YAG) laser is recognized as the optimal modality for effective, precise and minimally-invasive ablation of hard dental tissue [1,2]. Among all infrared lasers, the Er:YAG laser wavelength exhibits the highest absorption in water and hydroxyapatite and thus is ideally suited for the cold 'optical drilling' of enamel, dentine and composite fillings.

The development of dental lasers has been very rapid in the past years. [3,4] The optical ablation speeds of the latest Er:YAG lasers, with their variable square pulse (VSP) technology, now exceed the drilling speeds of conventional burs [5-10]. In a recent study, laser ablation with MAX mode [11] of the Er:YAG laser was found to be more efficient than high-speed drilling in enamel and the still burr drilling in dentin. [10] The volume of enamel cavity prepared using the Er:YAG laser was 3.3 times as large as the volume of enamel prepared using a high-speed handpiece. In dentin, the Er:YAG laser removed a volume 8 to 18 times as great as the steel burr. Measurements of maximum available optical drilling speeds were made under realistic conditions, identical to a manually performed laser treatment by the dental practitioner. These findings were similar to those in [7,9] where a comparison was made of the ablation speeds of the two main erbium laser wavelengths currently employed in dentistry, Er:YAG (2940 nm) and Er,Cr:YSGG (2780 nm). In comparison with the Er,Cr:YSGG laser, the Er:YAG laser operating in MAX mode was found to be faster in enamel by a factor of 4, and faster in dentine by a factor of 3.

SEM analysis of the enamel and dentin after the Er:YAG preparation with the MAX mode shows cavities with well-defined rims. No significant surface alterations, such as melting or carbonization were observed. The smear layer is completely removed, leaving open dentinal tubules and offering a micro-retentive pattern essential for adhesive restorative materials. [7,9,10]

In this paper, we report on a clinical study [12] of the safety of cavity preparation with high fluence, MAX mode Er:YAG laser pulses.

II. MATERIALS AND METHODS

The Er:YAG laser used in the study was a Fotona dental laser (model AT) fitted with a tip-less (non-contact) handpiece (beam spot size in focus: 0.6 mm), operating in the MAX mode (1000 mJ, SP pulse duration, 20Hz, 20 W). The most recent

model from the AT Er:YAG laser system family is shown in Fig. 1.

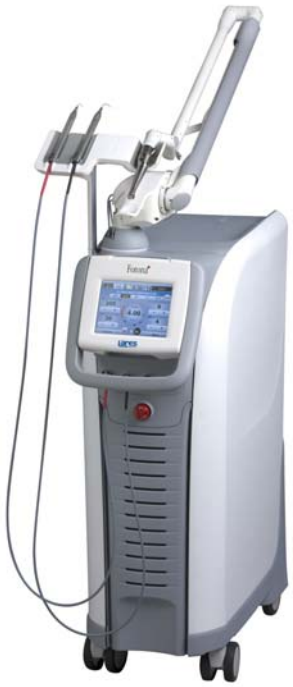

Fig. 1: Er:YAG dental laser system
(Fotona LightWalker AT)

The research protocol and the consent forms were approved by the appropriate ethical committee prior to the study. The patients were between 18 to 40 years old. Patients with third erupted molars requiring extraction were included in the study. Pre-treatment radiographs were taken for each tooth selected to ensure the absence of periapical pathologies and proximal caries. Teeth were also checked for the absence of signs of inflammation. The teeth were isolated with cotton rolls, dried and tested for pulpal vitality by testing the response to heat, cold and by the electrical test.

Three examination groups of patients were randomly selected (see Table 1).

Table 1: Examination groups used in the study

Groups	Positive Control	Negative Control	Laser Group
Extraction Time	(Bur cavities)	(No cavities)	(Laser cavities) Maximum mode 1000mJ – 20 Hz Er :YAG
Immediate	6	6	6
1 week	6	6	6
1 month	6	6	6

Sixty erupted caries and restoration-free third molars requiring extraction were used in the study. Six teeth having no cavity preparation were used as negative controls (NC). Fifty four teeth were submitted to the following treatments:

- Positive control (PC): Teeth were prepared with a high speed diamond bur (Standard 837R, Diatech, Switzerland) at 200,000 rpm with air/water cooling.
- Laser group (MAX): Teeth were prepared with the Fotona AT Er:YAG laser MAX mode (2.94 μm, 1000 mJ, 20 Hz, 20 W).

The cavities in groups PC and MAX were prepared without extension in the buccallingual direction with a standard irradiation time of 15 sec. Buccal-lingual dimensions were always equivalent to the bur diameter or the laser spot. A periodontal probe was used to control the depth. The teeth were prepared by moving the hand-piece continuously from mesial to distal and then back so that the target area was irradiated for a total of 15 sec. All patients were anesthetized before cavity preparation. The patients scheduled for immediate extraction were directly submitted to surgery. The patients scheduled for later extraction (1 week or 1 month) had their cavities sealed with a resin modified glass-ionomer cement (Vitremer/3M ESPE, St. Paul, MN, USA). These patients were asked to answer questions about the presence of pain 1 day, 3 days, 1 week and 1 month (where relevant) after cavity preparation by completing the questionnaire shown in Fig. 2 below.

Patient number: ……
Date of treatment: ……..
Date of surgery: ……..

Day after
◊ No pain at all
◊ Pain after ingestion of with cold liquids, which disappears after stimulus removal
◊ Pain after ingestion of with cold liquids, which persists more than 15 minutes after stimulus removal
◊ Pain after ingestion of with hot liquids

Three Days after
◊ No pain at all
◊ Pain after ingestion of with cold liquids, which disappears after stimulus removal
◊ Pain after ingestion of with cold liquids, which persists more than 15 minutes after stimulus removal
◊ Pain after ingestion of with hot liquids

1 Week after
◊ No pain at all
◊ Pain after ingestion of with cold liquids, which disappears after stimulus removal
◊ Pain after ingestion of with cold liquids, which persists more than 15 minutes after stimulus removal
◊ Pain after ingestion of with hot liquids

1 Month after
◊ No pain at all
◊ Pain after ingestion of with cold liquids, which disappears after stimulus removal
◊ Pain after ingestion of with cold liquids, which persists more than 15 minutes after stimulus removal
◊ Pain after ingestion of with hot liquids

Fig. 2: Questionnaire for the patient discomfort and pain evaluation

After surgical extraction the teeth were collected and the root ends removed to allow penetration of

the fixate into the remaining pulp tissue. The teeth were then placed in a 10% solution of formalin fixate for 48 hours. Following this the specimens were decalcified, sectioned and mounted onto slides. They were stained with hematoxylin end eosine. Visual inspection was performed with a microscope (Olympus BX-SO, Olympus Co., Ltd., Tokyo, Japan) at 2Sx. Two examiners who were blinded to the treatment modality, and previously calibrated to the rating of events that occur in studies investigating pulpal responses to clinical procedures, viewed the histological sections.

The score tables for the pulpal and inflammatory cell response are shown in Tables 2 and 3.

Table 2: Score table for tissue disorganization

Score	Characterization
0	Normal tissue
1	Odontoblastic layer disorganized but central pulp normal
2	Total disorganization of the pulp tissue morphology
3	Pulp necrosis

Table 3: Score table for the inflammatory cell response

Score	Characterization
0	None or few scattered inflammatory cells present in the pulp area corresponding to the axial wall, characteristic for normal tissue
1	Slight inflammatory cell infiltrate with polymorphonuclear or mononuclear leukocytes
2	Moderate inflammatory cell infiltrate involving the coronal pulp
3	Severe inflammatory cell infiltrate involving the coronal pulp or characterizing abscess

The sensitivity of the patients after the cavity preparations were ranked and compared between the groups. The data was analyzed using Fisher's exact test.

III. RESULTS

Histological examination disclosed no indication of inflammatory response in the pulp tissue at any time point ($p<0.005$). All sections appeared normal with no changes seen in the normal pulp morphology ($p<0.05$).

Of the teeth in the immediately extracted group only 1 tooth in the laser (MAX) group and 1 tooth in the PC (burr) group showed slight inflammation. Only one patient in the laser (MAX) group and 1 patient in the PC (burr) group reported slight sensitivity at 3 days after cavity preparation.

The results scores for the three groups at times immediately, 1 week and 1 month after cavity preparation are shown in Table 4.

Table 4 : Result scores for groups NC, PC and MAX at times immediately, 1 week and 1 month after cavity preparation

NC					PC (Bur)						MAX mode					
					0 days		1 week		1 month		0 days		1 week		1 month	
Pat. No	Inf	Tis Org	Inf	Tis Org	Inf	Tis Org	Inf	Tis Org	Inf	Tis Org	Inf	Tis Org	Inf	Tis Org	Inf	Tis Org
1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0

Typical histological results are shown in Fig. 3 for the NC group, Fig. 4 for the PC group and Fig. 5 for the MAX (laser) group.

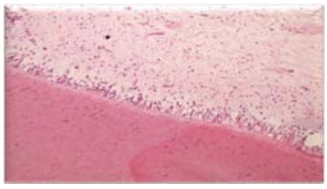

Fig. 3: Typical histological result for the NC (negative) group.

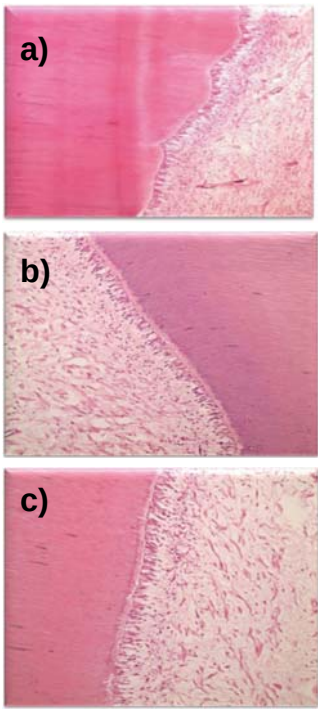

Fig. 4: Typical histological result for the PC (bur) group: a) immediate situation; b) 1 week situation and c) 1 month situation.

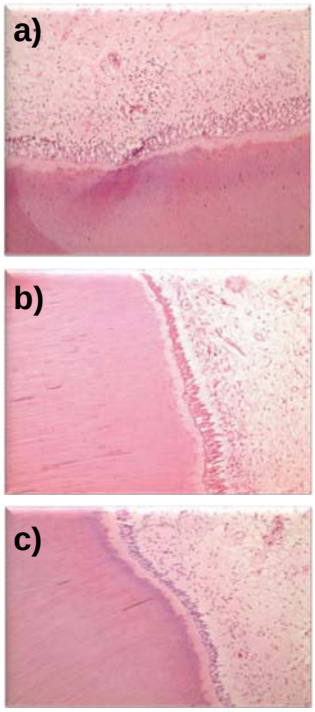

Fig. 5: Typical histological result for the MAX (laser) group: a) immediate situation; b) 1 week situation and c) 1 month situation.

IV. DISCUSSION AND CONCLUSIONS

Dental Er:YAG lasers operating in high speed MAX mode cause no permanent pulpal damage and can be safely used for fast cavity preparation. No permanent pulpal damage was observed. The maximum score value for inflammation and tissue disorganization was 1 in isolated cases on a scale of 0 - 4.

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