

PIT FORMATION ON DENTAL HARD TISSUES USING TWO DIFFERENT FREE ELECTRON LASER SOURCES, LEBRA-FEL AND KU-FEL

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Abstract

According to the increased usage and demands of lasers in dentistry, research and development of the more reliable and functional lasers are needed. In the case of caries treatment, the lasers generated by commercial apparatus are not enough to dig the dental enamel and/or dentin tissues. Our previous studies showed that FEL generated at LEBRA has a potential to form pits on these dental hard tissues easily, and that the effective wavelength depends on the tissue types sensitively at about 3000 nm. To progress the FEL study on dental tissues, it is needed to spread the range of wavelengths more than that at LEBRA, between 2000 and 6000 nm. The newly established KU-FEL is able to generate the FEL of wavelength between 5000 and 13000 nm. Combining the two FEL sources, we found a new result that the dental hard tissues were easily dug by 7600 nm KU-FEL, which wavelength has not been presumed before. In the combination of LEBRA-FEL and KU-FEL, the wider knowledge on the FEL action on dental tissues will be achieved.

INTRODUCTION

Lasers in Dentistry

Just after the first ruby laser was developed [1], dental researchers studied possible application of laser energy to dig dental enamel without pain [2]. Now, lasers have been applied in dentistry to sulcular debridement (Curettage) and reduction of bacterial level, treating periodontitis, root planing, pain control, wound healing, diagnosis of caries, and hard tissue applications using a variety of laser systems including CO₂ (10600 nm), Er:YAG (2940 nm), Ho:YAG (2100 nm), Nd:YAG (1064 nm), diode (810, 980 nm), Ar (514, 488 nm).

ADA (American Dental Ass., 2009) stated that while

Er:YAG and Er, Cr:YSGG (2780 nm) lasers be an alternative method of removing enamel, dentin and caries, clinicians are encouraged to be cautious and to be aware of the benefits and risks using lasers.

Generally, all the three emission modes (continuous, gated-pulsed, and true-pulsed) used in dental clinical lasers produces the thermal effects [3]. A limited studies on FEL application to dental hard tissues were reported. FEL irradiation, on the other hand, revealed that LEBRA-FEL did not show any apparent heat-effects but did show the formed pit deepness being correlated with the output and wavelength [4].

More recent studies on FEL-dental tissue interaction using KU-FEL showed that dental enamel was dig easily with the other wavelengths than the optimal, 2940 nm. This study aimed to clarify the FEL-dental tissue interaction mechanism using two different FEL sources.

Laser-Tissue Interaction

The principle mechanism of action of laser energy on tissue, known at now, is photothermal, other mechanisms may be secondary to this process [5]. Rapid heating of water molecules within enamel (ca. 96 wt% biological apatite, 2 wt% organic and 2 wt% water) causes rapid vaporization of the water and build-up of steam which causes an expansion that ultimately over comes the crystal strength of the tissue and the materials breaks, by exploding, this process is called ablation. Fig.1 showed the reported FT-IR data for water and hydroxyapatite. Biological apatite, which is the main inorganic component of bone and tooth, is a sub-family of hydroxyapatite, and a chief characteristics is a remarkable carbonate substitutions up to 8 wt% [6]. It is notable that there is a structural OH in the apatite crystal structure, but there is no remarkable absorption around 3000 cm⁻¹ in the spectrum.

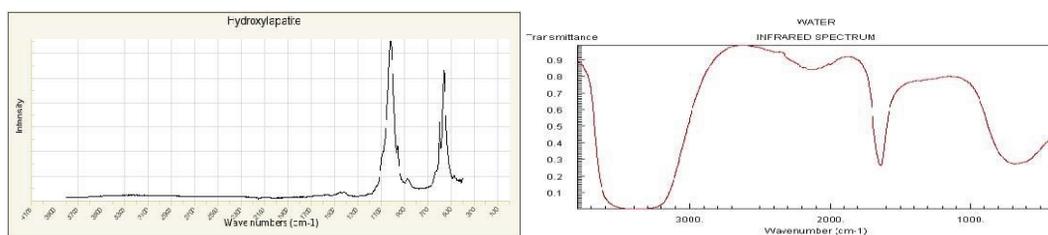


Figure 1: FT-IR data for (left) Hydroxyapatite (RRUFF File), and (right) Water (NIST).



Figure 2: LEBRA-FEL irradiation on the human tooth section resulted in the round pit formation.

This mechanism also implies to dentin (70 wt% biological apatite, 20 wt% organic, 10 wt% water), bone (50 wt% biological apatite, 30 wt% organic, 20 wt% water) and the other hard tissues. Photothermal effect: The rate of temp. rise depends on several factors. Rise of tissue temp. will give severe damage. Dental tissues have complex composition, and the four interaction phenomena occur together in some degree relative to each other: 1) absorption, 2) transmission, 3) reflection, 4) scattering. Among these, 2) through 4) has no effect on the target tissue, but harmful to the patient and operator.

MATERIALS AND METHODS

The target dental tissues were human tooth enamel and dentin. The reported compositions for human enamel are ca. 96 wt% inorganic (biological apatite), 2 wt% organic (enamel protein) and 2 wt% water; for dentin ca. 70 wt% inorganic, 20 wt% organic (mainly collagen) and 10 wt% water. Human teeth used in this study were the extracted by orthodontic reasons and pooled samples before the ethics committee at our school was established. The tooth samples were made into slices using a precision diamond wafering saw, IsoMet, Buehler Co. Ltd.

These sliced tooth samples were irradiated by the two FEL sources, LEBRA-FEL, Nihon University, and KU-FEL, Kyoto University. The details for the specs of LEBRA-FEL and KU-FEL were presented at the other corner in this proceedings. The principle conditions used in this study were as follows; LEBRA-FEL: 2940 nm, 1.5 mJ/pulse, 50 mJ/cm², KU-FEL: 7600 nm, 0.8 mJ/pulse, 13 mJ/cm

RESULTS AND DISCUSSION

Both FEL sources made apparent remarkable pit formation on the dental tissue surfaces (Fig. 2 and 3). Pits were formed on both enamel and dentin surfaces without apparent scar.

LEBRA-FEL tuned at 2940 nm, the so-called optimum wavelength, could form pits easily both on the tooth enamel and dentin (Fig.2). And the previous studies using

the tunable LEBRA-FEL revealed that the tissue dependent optimum wavelength for enamel and dentin. The other wavelengths, between from 2000 nm to 6000 nm, using LEBRA-FEL failed to form any pits [7].

Contrary to expectations, KU-FEL, 7600 nm and less fluence, could easily form pits on both enamel and dentin without scars (Fig. 3). Clinically used lasers about this wavelength range generally show the photothermal effect and scars on the soft tissues and no pit formation on the hard tissues [8].



Figure 3: KU-FEL irradiation on the human tooth section resulted in the streaked pit formation. The streak form pit may be due to the not-well adjustment of the optical path system.

The results obtained here are not easily explained by the well known principles for the dental tissues and laser interaction. There arose some questions to be clarified such as;

Question 1: If water explosion is the main cause for the dental tissue destruction, why the optimum wavelength is differing among the tissues?

Question 2: What is the mechanism for the dental tissue and FEL interaction?

CONCLUSION

The FEL irradiated pit formation on tooth surface has been made in the principle which is different from that being widely accepted “photothermal or water explosion” mechanism. It is suggested that the basic researches on application of FEL will help to develop a new horizon of lasers in dentistry. The FELs have a potential ability for dental clinical usage.

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