Effect of Ultra Short Pulse Laser on dentin structural changes and surface roughness

Ola. M. Sakr

Departments of Operative Dentistry, College of Dentistry, Qassim University, Kingdom of Saudi Arabia & Misr University for Science and Technology\, Egypt
olasakr2004@yahoo.com

Abstract: In this study, the structure, and surface morphology of dentin after ablation with ultra-short pulses (USPL) were evaluated using environmental scanning electron microscopy (ESEM) with EDAX analysis and scanning electron microscope micrographs. The dentin specimens examined were irradiated by (100, 300 and 400 mJ) of ultra short pulse laser . Based on EDAX results, it was possible to identify the suitable energy density as the ablation threshold for dentin. The results demonstrate that by selecting suitable parameters one can obtain efficient dentin surface preparation without evidence of structural changes and thermal damage, i.e., with minimized heat affected zones and reduced collateral damage, which characterized by formation of microcracks , grain growth and recrystallization in the heat affected zones.

[Ola. M. Sakr. **Effect of Ulrra Short Pulse Laser on dentin structural changes and surface roughness.** *Life Sci J* 2012;9(4):957-962] (ISSN:1097-8135). http://www.lifesciencesite.com. 148

Keywords: Dentin, USPL ablation, Surface structure modification, EDAX, ESEM

1. Introduction

Several approaches for localized, painless, rapid laser treatment of dental hard tissue have been the aim of different continuing researches [1-3]. The hard dental structure comprises several layers, enamel, dentin, cementium and pulp. The dentin is the major constituent of teeth and consists of 70% hydroxyaptite crystals [Ca10(PO_4)6($OH)_2$], 20% organic matter (collagen fibers) and 10% water. Its internal structure consists of dentinal tubules, which are essential for the sensation and growth of the tooth [4,5] . Dentin hypersensitivity is characterized by short sharp pain arising from exposed dentin in response to stimuli . The stimuli may be thermal, evaporative, tactile, osmotic or chemical. Most commonly, cases of dentine hypersensitivity are associated with erosion or gingival recession. Dentin hypersensitivity is one of the most common complications that affect patients after periodontal therapy and is reduced when the dentinal tubules are occluded. Several attempts have been performed previously to obtain closure of dentinal tubules using Nd:YAG laser treatment by inducing melting and resolidification of the dentin [5,6]. Studies of dentin ablation with Er:YAG and Ho:YAG lasers have indicated several weaknesses in the surface preparation process expressed in heat accumulation, fissuring and slow material removal rates. The attempts to apply these lasers to certain procedures in dentistry, especially for caries therapy in order to replace conventional drilling, have not been fully successful. Due to the high absorption of Er:YAG radiation by water molecules in the dentin tissue, the preparation process results in micro explosions breaking the hydroxyapatite structure and leading to the appearance of microcracks [7].

These microcracks could become initial points for the development of new carious lesions. Modifications of these systems (Er, Cr:YSGG) have been introduced in the dental practice in combination with water spray in order to improve the surface preparation by cooling the ablated region and increasing the ablation rate[8-10] . In recent studies, new ultra-short laser techniques for modification and structuring of dental hard tissue have emerged as a promising tool and an alternative to Er:YAG lasers [11-13] due to the advantages expressed in negligible heat and shock wave impact. The interaction of high-intensity ultra-short laser pulses with materials is characterized by fewer thermal side effects. Studies of the surface topography evolution in dentin processed by femtosecond lasers revealed surface effects, such as sealing of dentinal tubules, microdrilling of human enamel and dentin for caries treatment. Depending on the dental treatment procedure to be performed, one could utilize different types of laser-induced physical effects to obtain maximum benefits. For example, the effect of melting is used for sealing dentinal tubules in order to reduce dentin hypersensitivity and pathogenic agents' penetration. This procedure has so far been carried out by CO2, Ho:YAG and Er:YAG lasers; however, the thermal side-effect associated with the use of these conventional lasers like appearance of a heat affected zone in the order of micrometers, results in rough surface structuring with deep cracks [14,15]. The present study was motivated to detect the microstructure of dentin surfaces after different energy levels of ultra-short pulse laser ablation.

The review of literature revealed that the application ultra short pulse laser with duration <50 fs for ablation of dental tissue, followed by examination with ESEM , EDAX analysis and different energies and their effect on dentin, has been rarely attempted. Few studies have been performed to compare the use of different number of femto second laser pulses [14,16]. The purpose of our study was to obtain and understanding on the structure and morphological changes of the dentin surface after three different energies of ultra-short laser ablation of dentin.

2. Materials and Methods:

I- Preparation of the samples:

A total of 30 of human molar teeth were extracted for periodontal diseases. The teeth were free from visible caries and other surface defects. Teeth were cleaned with a rotary brush and pumice and stored in saline and used within 6 months from time of extraction to inclusion in the study. The roots were sectioned 2 mm beyond the cemento-enamel junction .The occlusal enamel was removed by horizontal sectioning till reaching the dentin just below the dentinoenamel junction using the Isomet slow-speed diamond saw (Isomet 1000; Buehler, Lake Bluff, IL, USA). The dentin surface was abraded with decreasing grits of silicon carbide (SiC) paper (from #800 to # 1200) under water-cooling for 30 s/ paper. A standard superficial dentin surface of about 0.5 mm from dentinoenamel with standard smear layer was produced.

II- Sample classification:

The total 30 samples were classified into three main groups:

Group I: 10 samples for ablation with100 mJ ultra short pulse laser

Group II: 10 samples for ablation with 300 mJ ultra short pulse laser

Group III: 10 samples for ablation with 400 mJ ultra short pulse laser

III- Laser ablation condition:

Dentin surfaces were ablated by Ultra short pulsed laser (USPL). Its wavelength range was around 2940 nm in infra red region. Spot size was 3 mm. The beam was applied perpendicularly to the specimens, with the tested different energies of (100, 300, 400 mJ).

IV-Topographic evaluation:

The Scanning Electron Microscopic (SEM) examination and microanalysis were carried out using QUANTA 200 scanning electron microscope attached with EDAX unit, with accelerating voltage 30 K.V. magnification 10x up to 400.00x

Results:

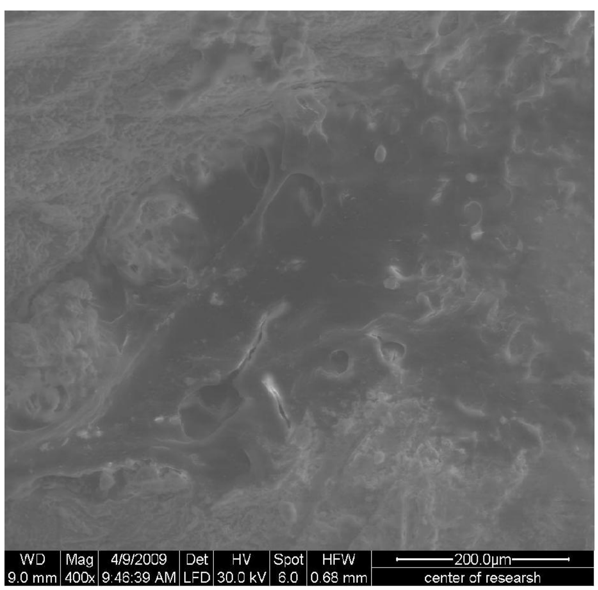
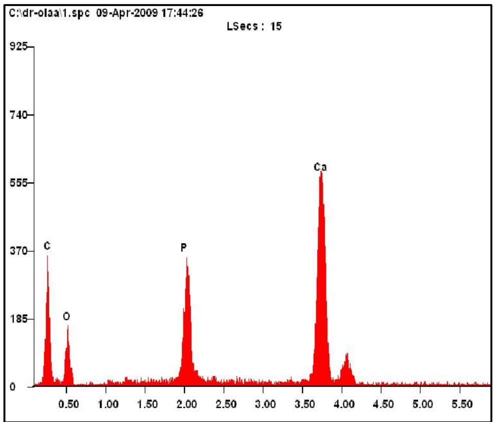
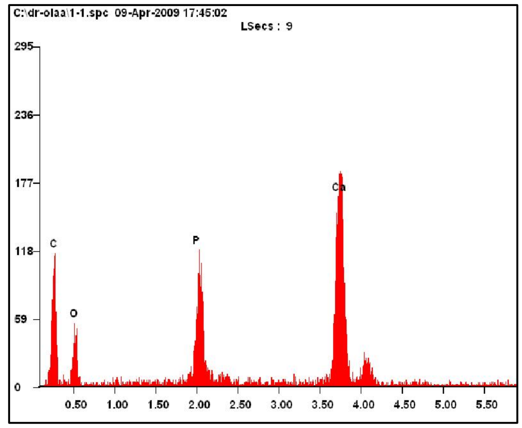
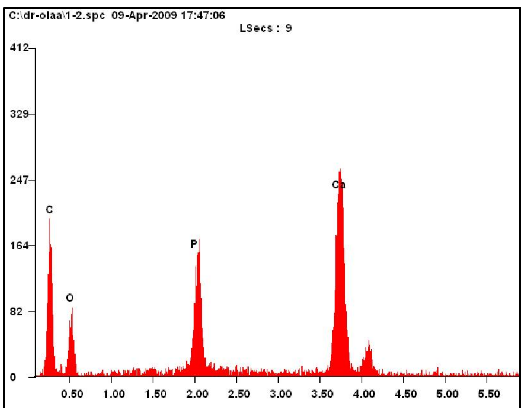


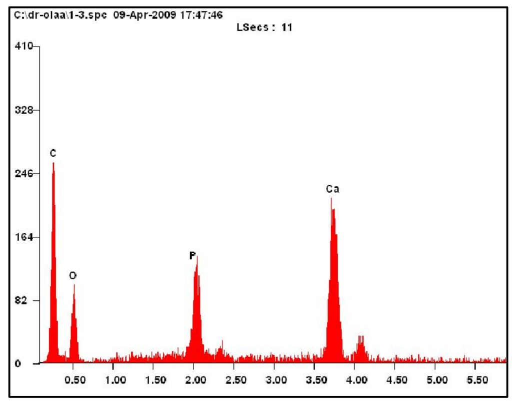
Fig.(1): Scanning electron micrograph showing dentin surface ablated with 100 mJ of USPL showing recrystalization and solidification





A(1ST point) B (2nd point)





C (3rd point) D (4th point)

Fig.(2): Four points EDAX microanalysis of first group showing highest carbon level and lowest calcium level

Element	*Wt %*	*At %*
C K	60.43	72.32
O K	23.90	21.47
P K	05.67	02.63
CaK	10.00	03.59

Table (1) :Mean of surface dentin elements , BY EDAX ZAF QUANTIFICATION , ablated with 100 mJ of USPL

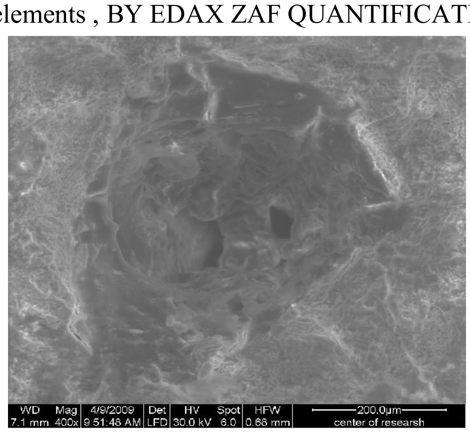
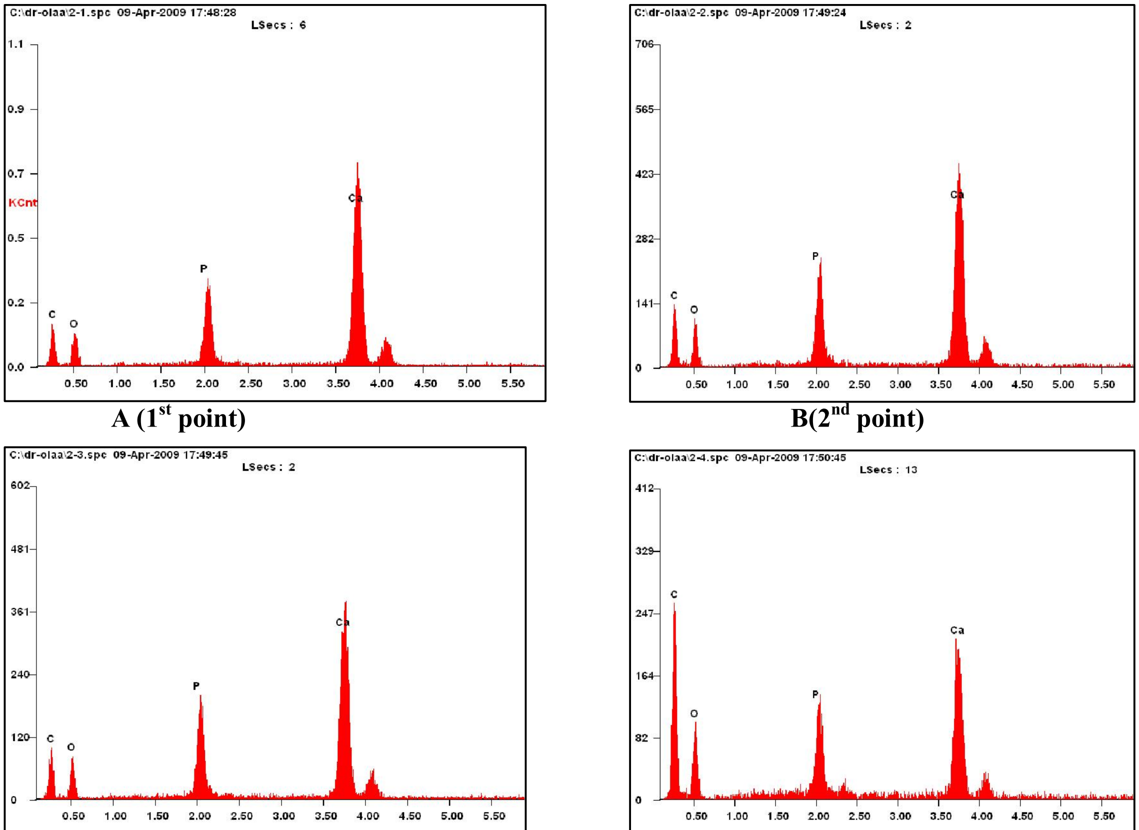


Fig.(3) : Scanning electron micrograph showing dentin surface ablated with 300 mJ of USPL showing crater like cavity



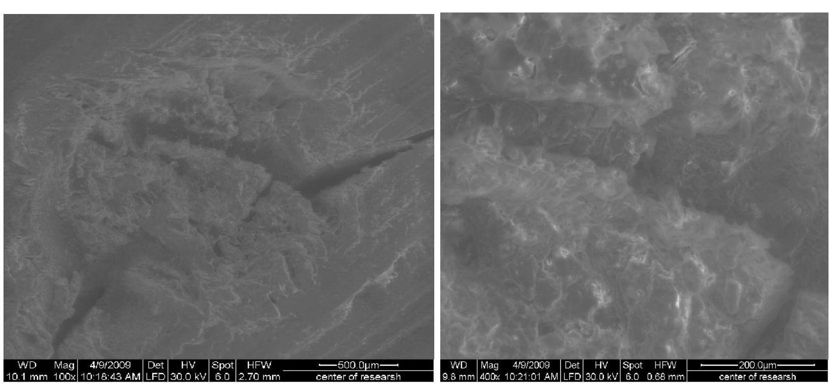
A (1st point) **B(2nd point)**

C (3rd point) **D (4th point)**

Fig.(4): Four points EDAX microanalysis of 2nd group showing moderate carbon and calcium level

Table (2): Mean of surface dentin elements , BY EDAX ZAF QUANTIFICATION , ablated with 300 mJ of USPL

Element	Wt %	At %
C K	48.92	62.79
O K	28.83	27.78
P K	07.73	03.85
CaK	14.52	05.58



A B

Fig.(5) : Scanning electron micrograph showing dentin surface ablated with 400 mJ of USPL showing increasing of surface roughness and cracking. A at 100 magnification , B at 400 magnification

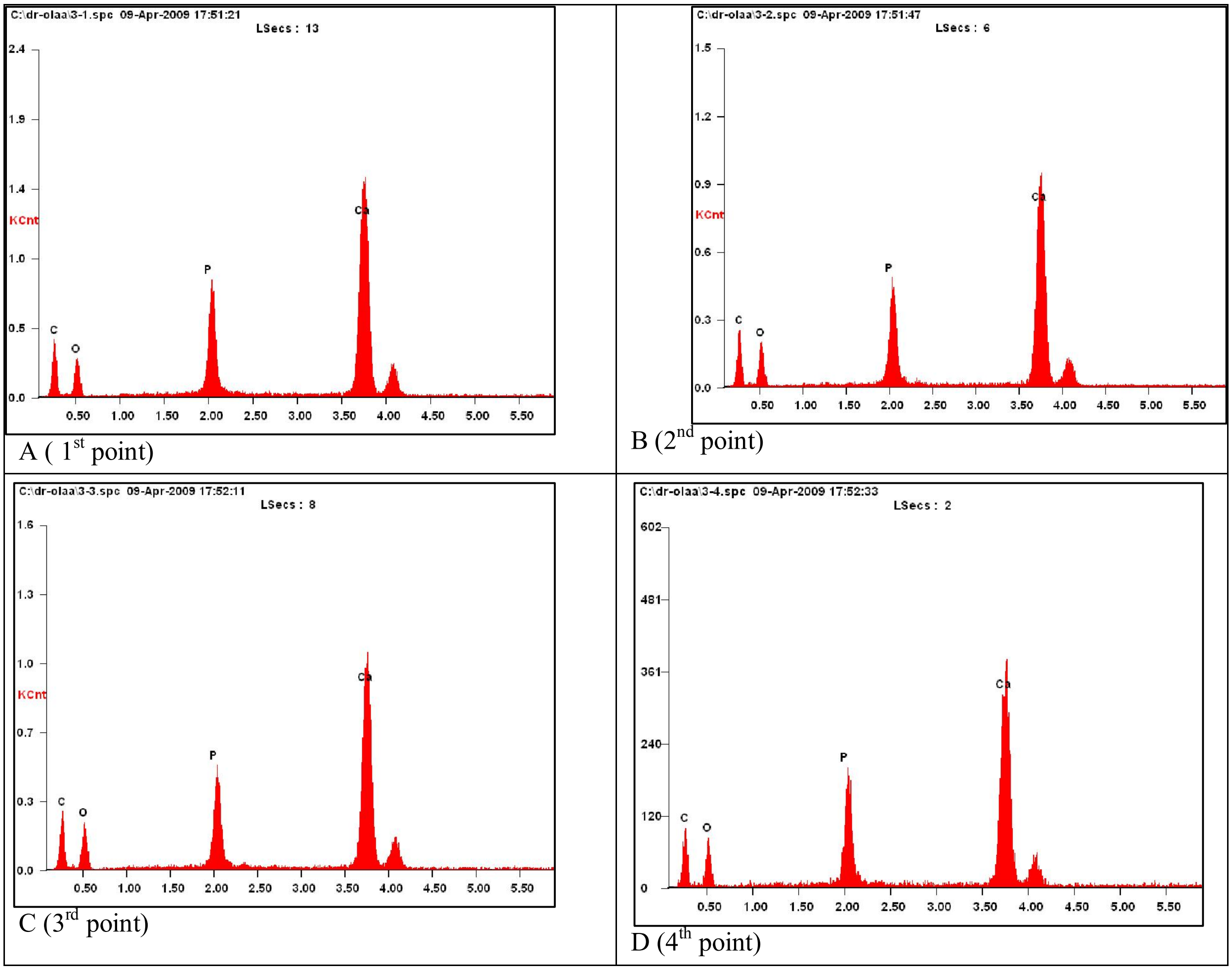


Fig.(6): Four points EDAX microanalysis of 3rd group showing lowest carbon level and highest calcium level

Table (3) :Mean of surface dentin elements , BY EDAX ZAF QUANTIFICATION , ablated with 400 mJ of USPL

Element	Wt %	At %
C K	47.01	61.43
O K	28.64	28.09
P K	08.18	04.15
CaK	16.17	06.33

4. Discussion :

The SEM micrographs of (first group)100mJ of USPL ablated dentin surface revealed a flat smooth without cracks surface with recrystalization and solidification of dentin (Fig. 1) . EDAX microanalysis(Fig.2 and Table 1) show highest carbon level and lowest calcium level .this evidence may be explained as lower USPL thermal effect on organic component of dentin tissue .The SEM micrographs of (2nd group) 300 mJ showed a development of a crater (Fig. 3) without cracking . EDAX microanalysis (Fig.4 and Table 2) show lower carbon level and higher calcium level than first group. This evidence may be attributed to increase of USPL thermal effect on organic component of dentin and melting of non organic component. The SEM micrographs of (3rd group) 400 mJ showed a development of a crater with cracking (Fig. 5). EDAX microanalysis (Fig.6 and Table 3) show lowest carbon level and highest calcium level. In this study, this evidence may be attributed to high energy density of USPL show thermal side effect on organic component of dentin. We can explain that thermomechanical ablation of dentin tissue, as Li *et al.,* ([17] mentioned in case of Er:YAG dentin ablation , by causing micro-explosions within inorganic structures in teeth. Then laser vaporizes water and other hydrated organic components until internal pressure causes the destructive explosion of the inorganic component before the melting point is reached. So increase of laser density may cause decrease in organic component of dentin and melting with rational increase to inorganic component of dentin. This results coincide with Daskalova *et al.,* [(16)] who stated that As the number of pulses was raised , the presence of cracks at the bottom of the ablated crater was observed, heat is generated in a volumetric region in depth. After a certain number of pulses, a sufficient amount of heat per pulse is deposited in a cumulative manner leading to an increase in the local temperature and initiating a process of thermal ablation followed by formation of cracks at the cavity bottom.

Conclusion:

-Dentin ablation with USPL in lower energies led to development of a characteristic molten morphological layer. These findings can be applied to achieve sealing of the dentinal tubules necessary for the prevention and treatment of an early-stage carious lesions and to make the tissue more resistant to development of new caries.

-There are a direct correlation between USPL energy level and thermomechanical ablation of dentin surface . So high energy levels of USPL should have restricted role clinically.

Corresponding author
Ola. M. Sakr
Departments of Operative Dentistry, College of Dentistry, Qassim University, Kingdom of Saudi Arabia & Misr University for Science and Technology, Egypt
olasakr2004@yahoo.com

References

1. Walsh L.J. (2003): The current status of laser applications in dentistry, Dent. J. 48; 146–155
2. Neev, J., L.B. Siiva, M.D. Feit, M.D. Perry, A.M. Rubenchik, B.C. Stuart, (1996): Ultra short pulse lasers for hard tissue ablation. IEEE Journal of Selected Topics in Quantum Electronics: 2: 790-799.
3. Yip H.K., L.P. Samaranayake (1998):Caries removal techniques and instrumentation ,:a review, Clin. Oral Investing. 2 148–154.
4. James KA (2000).: Essentials of oral histology and embryology. 2nd ed , Mosby Co, Inc.;P.: 94 - 106 ;
5. Giachetti, L., D. Scaminaci Russo, F. Scarpelli and M. Vitale, (2004): SEM analysis of dentin treated with the Er:YAG laser:A pilot study of consequences resulting from laser use on adhesion mechanisms. Clin Laser Surg Med., 22: 35.
6. Liu H.C., C.P. Lin, W.H. Lan (1997): Sealing depth of Nd:YAG laser on human dentinal tubules, J. Endod., 23 691–693.
7. Attril DC , Davies RM , King TA , Dickinson MR and Blinkhorn AS (2004): Thermal effect of Er:YAG lasers on simulated dental pulp : a quantitative evaluation of the effect of water spray . J Dent Res , 32: 35-40.
8. Visuri S.R., J.T. Walsh Jr., H.A. Wigdor, (1996) : Shear strength of composite bonded to Er:YAG laser-prepared dentin, Lasers Surg. Med. 18 294–300.
9. Apel C., J. Meister, R.S. Ioana, R. Franzen, P. Hering, N. Gutknecht (2002): The ablation threshold of Er:YAG and Er:YSGG laser radiation in dental enamel, Lasers Med. Sci., 17 ;246–252.
10. Ebihara A., B. Majaron, L-H.L. Liaw, T.B. Krasieva, P. Wilder-Smith (2002) : Er:YAG laser modification of root canal dentine: influence of pulse duration, repetitive irradiation and water spray, Lasers Med. Sci. 17: 198–207.
11. Kraft J.F., K. Vestentoft, B.H. Christensen, H. Lovschall, P. Balling (2008): Calculus removal on a root cement surface by ultrashort laser pulses, Appl. Surf. Sci., 254 :1895–1899.
12. Ozono K., M. Obara(2003): Tailored ablation processing of advanced biomedical hydroxyapatite by femtosecond laser pulses, Appl. Phys. A 77; 303–306.
13. Kamata M., T. Imahoko, K. Ozono, M. Obara(2004): Materials processing by use of a Ti:sapphire laser with automatically-adjustable pulse duration, Appl. Phys., A79:1679–1685.
14. Chung S., E. Mazur (2009): Femtosecond laser ablation of neurons in C. elegans for behavioral studies, Appl. Phys., A; 96 335–341.
15. Lin C.P., B.S. Lee, S.H. Kok, W.H. Lan (2000): Treatment of tooth fracture by medium energy CO2 laser and DP-bioactive glass paste: thermal behavior and phase transformation of human tooth enamel and dentin after irradiation by CO_2 laser, J. Mater. Sci.: Mater. Med. 11:373–381.
16. Daskalova A., S. Bashirb, and W. Husinsky (2010): Morphology of ablation craters generated by ultra-short laser pulses in dentin surfaces: AFM and ESEM evaluation. Applied Surface Science 257; 1119–1124.
17. Li ZZ, Code JE and Van de Merwe WP(1992): Er:YAG laser ablation of enamel and dentin of human teeth: determination of ablation rates at various fluencies and pulse repetition rates. Laser Surg Med., 12:625–30.

5/21/2012