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# Combined Effects of Erbium : YAG laser and Fluoride Application on Acid Resistance of Tooth dentin in vitro

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## Abstract

This study examined the inhibition of dentin demineralization in initial caries with Er : YAG laser irradiation only and laser irradiation combined with fluoride application. Dentin blocks were prepared from the roots of bovine incisors and pretreated with one of the following five procedures : A) untreated, B) Er : YAG laser irradiation for 5min at 50mJ/pulse, C) APF gel application for 5min, D) Er : YAG laser followed by APF application for 5min,and E) APF treatment for 5min followed by Er : YAG laser irradiation. Subsequently the samples were demineralized in a 0.1M lactic acid gel (pH5.0) containing 6wt% CMC at 37°C for 2 weeks. The mineral distributions in the dentin surfaces were assessed quantitatively by transversal microradiography (TMR) and videodensitometry. The mineral parameter values were not significantly different for samples with and without laser treatment at $p=0.05$, as tested by paired t-tests. The present results suggest that the progress of demineralization in dentin lesions is not effectively inhibited by the single treatment with laser irradiation. Combined Er : YAG laser and APF treated samples had the highest acid resistance with significantly lower lesion depth (ld) and mineral loss ($\Delta Z$) values lower even than the APF treated samples.

**Key words** : Erbium : YAG Laser, Fluoride, Dentin, Microradiography

## Introduction

Recently, lasers have been introduced in dental treatment and some types of laser, like CO2, Nd : YAG and Er : YAG lasers have been suggested to provide / aid caries preventive effects in intact enamel by improving the acid resistance[1-3]. In most studies, the acid resistance of

This study was partly presented at the 7th ISLD Congress on Laser in Dentistry July 30-August 2, 2000
Received September 30.

enamel surfaces has been assessed generally by the Ca dissolution rate. From cariologic considerations, however, one drawback of the Ca dissolution test is that the acid etching procedure of the test does not simulate caries attacks except in the erosion of enamel and dentin. Therefore, it is necessary to examine if laser irradiation can prevent early caries lesions in enamel or dentin after long-term acid exposure to an acid gel system.

The Er : YAG laser has been investigated for applications in the field of periodontics. Here, root caries, often occurring in the elderly and in patients undergoing maintenance therapy after periodontal treatment, appears to be a typical stance where laser treatment could be helpful.

With the increase in the number of elderly patients in recent years, very many patients with dental roots exposed as a result of periodontal ailments have been observed clinically. Because dentin and cementum have low mineral density and little acid resistance, these exposed roots are likely to develop into root caries. However, an effective method to prevent this kind of caries has not been established. Traditionally, fluoride has been used as a tool for caries prevention, serving to enhance enamel acid resistance. Dentin, having a different composition and histology, needs a different approach toward enhancing its caries prevention effect however. Recent studies have reported a new treatment for caries prevention using laser irradiation of enamel.

The aim of this study was a microradiographic assessment of whether a combination of Er : YAG laser irradiation and fluoride protects demineralized dentin from lesion formation under caries simulation using a viscous acidic gel which is known to produce caries-like lesions successfully by acting as dental plaque.

## Materials and Methods

### 1. Sample preparation

Bovine incisors were used in this study. After removal of the crown, the roots were separated into two parts (buccal and lingual) using a water-cooled diamond saw (Isomet, Buhler, U.S.A.). These were mounted on an acrylic plate and except the original dentin surfaces were completely coated with an impression compound (Pericompound Shofu, Japan)

Subsequently, the dentine surfaces were slightly abraded with wet abrasive paper (grit 800) to provide flat areas of about $15mm^2$.

### 2. Treatment

The dentin samples (n=60) were divided into 5 groups and pretreated with one of the following procedures ;

A) Non lased (control).

B) Er : YAG laser irradiation only

C) APF gel application for 5 min, and no laser irradiation

D) APF treatment for 5min followed by Er : YAG Laser irradiation

E) Er : YAG laser irradiation followed by APF treatment for 5min.

The APF gel was removed from the dentin surface and followed by plentiful air-water spray rinse.

The Er : YAG laser was irradiated to the target region under a water spray (water ; 30 mL/mim air ; 1.5 kgm/psi), at an energy setting of 50 mJ/pulse and a pulse repetition rate of 10 pulses per second (pps) using an Erwin (ERW1 : HOYA Co. and MORITA Co.) Er : YAG laser apparatus.

### 3. Demineralization (acid attack)

After the pretreatments, the dentin surfaces of the samples were demineralized by immersion in a 0.1M acid gel (pH5.0) containing 6wt% carboxymethylcellulose (CMC) at 37°C for 2weeks. The gel volume was always at 100ml per 6 samples.

### 4. Microradiography

After demineralization, thin planoparallel sections of about 300$\mu$m thickness were cut from the dentin samples using a water-cooled diamond coated saw under running tap water. The sections were ground planoparallely on a wet 800-grit abrasive paper to a thickness of about 100$\mu$m.

They were microradiographed together with a reference aluminum step wedge using Cu-K$\alpha$ radiation (PW-1830, Philips, The Netherlands) generated at 20kV and 15mA for 24s. For the methodology of the transveral microradiograhy (TMR), we referred to de Joselin de Jong, et al.[4,5].

As shown in Fig. 1, a mineral profile was processed from densitometric data and the two mineral parameters of interest, i. e., the lesion depth (1d,$\mu$m) and the mineral loss value ($\triangle$Z,vol%$\cdot\mu$m), were assessed by means of a computer-assisted video densitometry and a specifically designed program previously described in detail by Inaba et al.[4,5].

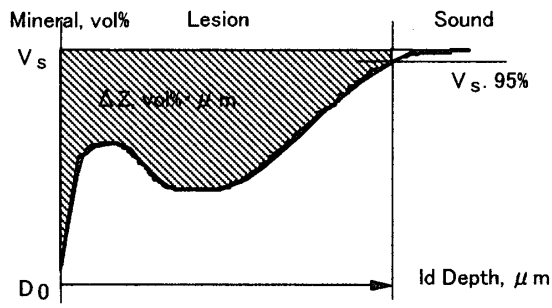


Fig. 1 Mineral distribution parameters in dentin caries lesions.
Vs=Sound mineral level, $D_0$=surface position, ld=lesion depth in $\mu$m, $\Delta$Z=mineral loss value in vol% $\cdot$ $\mu$m

## Results

The mean $l_d$ and $\triangle$Z values are shown compiled in Table 1, Fig.2 and 3. The mineral distributions of the dentin after acid exposure demineralization are shown in Fig. 4.

The $l_d$ values of the unlased control and lased samples were 104$\pm$12$\mu$m and 98$\pm$11$\mu$m (mean$\pm$SD), respectively ; $\triangle$Z values were2,621$\pm$222 and 2,493$\pm$256 vol% $\cdot$ $\mu$m (mean$\pm$SD). When the Er : YAG laser was combined with APF treatment $l_d$ values 37-41% reduced compared with the control group ($P<0.05$), and 34-38% compared with the Er : YAG laser treatment alone. There were no significant differences in either mineral parameter between

Table. 1 Comparison of microadiographical mineral parameters, the lesion depth($l_d$) and the mineral loss value($\Delta Z$)

| | Lesion depth ($l_d$) (Mean±SD) (μm) | mineral loss value($\Delta Z$) (Mean±SD) (Vol%・μm) | Reduction of Lesion depth(%) p※<0.05 |
|---|---|---|---|
| Control | 103.5±11.7 | 2621.4±221.8 | |
| Er:YAG laser irradiation | 98.3±11.1 | 2494.8±258.5 | |
| APF alone | 82.8±10.0 | 1515.6±346.8 | 37%※ 34% |
| Er:YAG laser irradiation before APF treatment | 65.0±16.6 | 1332.2±488.8 | 41%※ 38% 4% |
| APF treatment before Er:YAG laser irradiation | 61.2±12.1 | 1099.6±434.0 | |

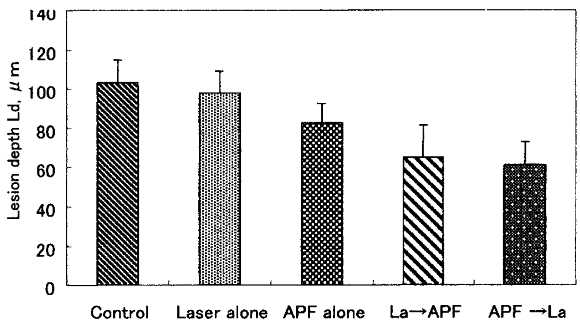


Fig. 2 Lesion depth values(ld). Bar=SD

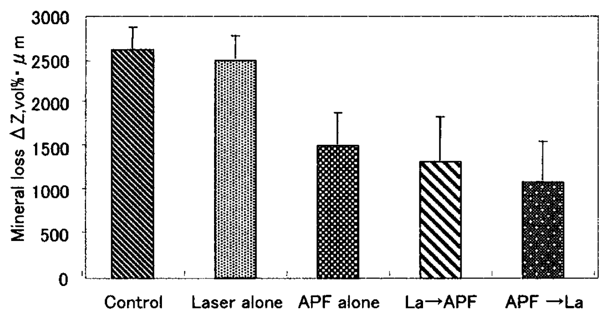


Fig. 3 Mineral loss values(ΔZ). Bar=SD

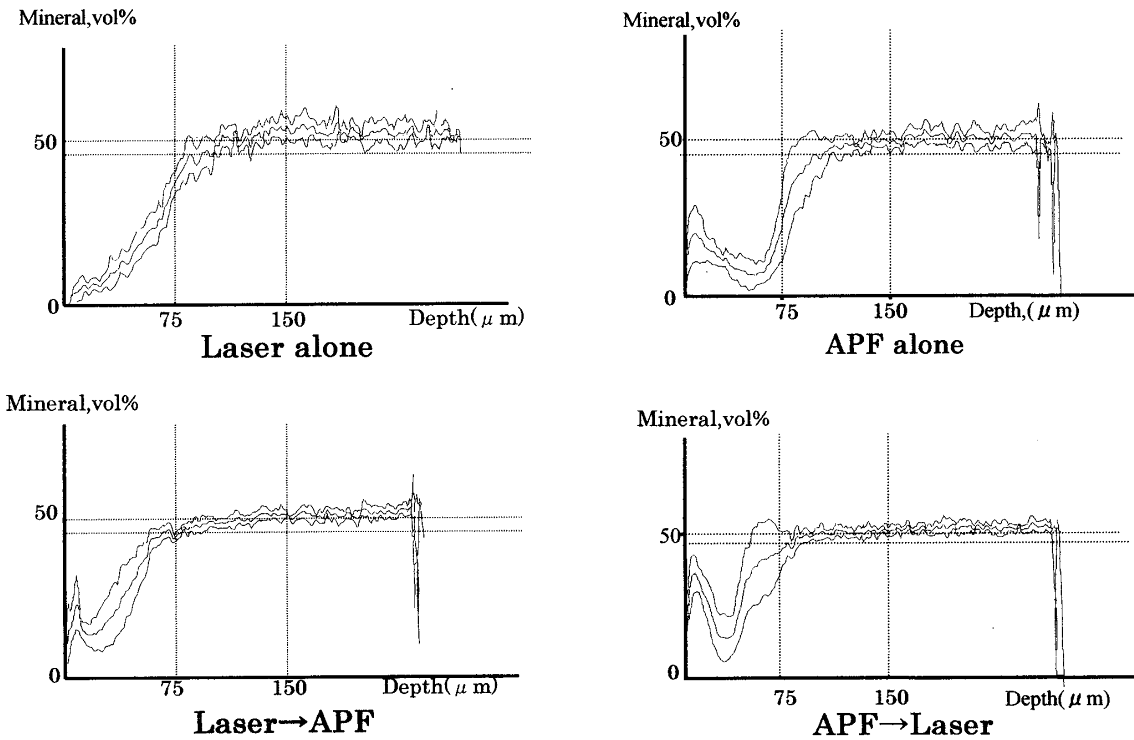


Fig. 4 Mineral distribution

the unlased and lased samples.

## Discussion

A number of studies have reported that the dental surface of Er YAG lased enamel becomes lubricated, acid permeability is lowered, and decalcification is controlled. Yet, few attempts have been made to examine dentin acid resistance and no relevant conclusions have been reached. The result of acid resistance test with Er : YAG laser irradiation have shown that a single one treatment of Er : YAG laser irradiation of the surface of exposed sound roots is effective in enhancing acid resistance. This is attributed to the fact that Er : YAG laser irradiation alone makes the surface of root dentin rough and fragile and considerably lowers the acid resistance. Moreover, unlike enamel, dentin has an about 65% mineral content, 20% organic substance content (mineral collagen), and 15% moisture content. In order words, it may be assumed that because the organic components do not evaporate by laser irradiation, the surface of dentin does not become lubricated like that of enamel and that the acid resistance does not become enhanced.

The combination of Er : YAG laser irradiation and fluoride treatment resulted in enhanced caries resistance when compared with a single treatment of Er : YAG laser irradiation. This effect appeared to be a synergistic and not an additive effect. In this study, APF gel was applied either before or after the laser irradiation and both resulted in significant reductions in lesion depths. The increased fluoride uptake may result in replenishment of fluoride within the lesion and it may also act as a reservoir for fluoride release during demineralization.

Several mechanisms for improved caries resistance by laser irradiation have been proposed. Some reports suggest that the altered pore structure of enamel and dentin combines with an increased affinity for fluoride, calcium and phosphate[6,7]. It is also possible that calcium, phosphate and fluoride ions, released from the mineral phases of enamel and dentin during caries formation, may reprecipitate into adjacent microspaces created in the mineral phases during the laser treatment.

The release of even small quantities of the fluoride from dentin during an acid exposure would result in rapid reprecipitation of mineral phases and would necessitate significant adjustment of pH for demineralization to occur.

The addition of fluoride to Er : YAG laser treatment would allow for incorporation of fluoride within the superficial dentin layers and this would favor precipitation of mineral phases mobilized from the subsurface of the tooth structure as well.

Under the conditions employed, the lased early caries lesions did not show remarkable acid resistance after 2week challenge of attack by an acidic gel, when compared with untreated controls.

The results obtained are different from previous laser studies in which relatively short exposure periods to an acidic solution were employed to assess acid resistance of lased sound enamel or dentin.

One possible explanation for the differences are in the acid exposure methods used. Etching for short times by acidic solution is suitable to evaluate the acid resistance of the outermost lased sound dentin.

An advantage of the plaque-like sticky gel system is that it enables an evaluation of the acid resistance of enamel (dentin) to a given depth by simulating a relatively slow, continuous reaction in the liquid phase between the outer environment and the tooth.

It may be asked why demineralization progressed in the lased caries lesions after application of the acid gel system for 2 weeks.

Here it may be speculated that surface layer produced by laser irradiation may not be uniform, and thermal effects of the laser irradiation and subsequent cooling may have formed cracks in the dentin surface, resulting in enhanced permeability.

The present results indicate that lased dentin at least did not prevent outer hydrogen ions from penetrating deeper into the body of a lesion.

## Conclusions

Under the conditions employed, and compared with untreated controls lased early caries lesions did not show remarkable acid resistance after an acid demineralization attack by an acidic gel for 2weeks.

The combined Er : YAG laser irradiation and APF gel application may be one way to enhance acid resistance.

## References

1. Fox JL , Yu D, Otsuka M, et al. : Combined effects of laser irradiation and chemical inhibitors on the dissolution of dental enamel., *Caries Res.*, **26** : 333-339, 1992.
2. Tagomori S, Iwase T : Ultrastructural changes of enamel exposed to a normal pulsed Nd : YAG laser., *Caries Res.*, **29** : 513-520, 1995.
3. Bahar A, Tagomori S : The effect of Normal pulsed Nd : YAG laser irradiation on pits and fissures in human teeth., *Caries Res.*, **28** : 460-467, 1994.
4. Inaba D, Takagi O, Arends J, et al.: A computer-assisted videodensitometric method to visualize mineral distributions in vitro and in vivo form root caries lesions, Eur. J. *Oral Sci.*, **105** : 74-84, 1997.
5. Inaba D, Tanaka R, Takagi O : Computerized measurements of microradiographic mineral parameters of de-and remineralizd dental hard tissues., *J. Dent. Hlth.*, **47** : 67-74, 1997.
6. Hicks MJ, Flaitz CM, Westerman GH, et al.: Caries-like lesion initiation and progression in sound enamel following argon laser irradiation : an in vitro study. ; *J Dent Child.*, **60** : 201-6, 1993.
7. Westerman GH, Hicks MJ, Flaitz CM, et al.: Argon laser irradiation in root surface caries in vitro.; *J Dent Res.*, 71, 210, 1992.