Eliminating effect of Er, Cr: YSGG laser irradiation on the smear layer of dentin

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Purpose: To observe morphological changes and elimination of smear layer on the dentin exposed to Er, Cr: YSGG laser using different energy and irradiating distance.
Materials and Methods: Twenty-two first premolars were selected and slices with 1.5 mm thickness were prepared by horizontal sectioning through the middle third of the teeth crown. The occlusal surface having been coated by smear layer were to be treated. Each dentinal slice was irradiated under the laser with different irradiating distance (<2 and 3 mm) and different energy (1, 2, 3, 4, and 6 W). After routine preparation for microscopic observation, the specimens were observed with a scanning electron microscope.
Results: Laser with energy of 2-6 W and irradiating distance below 2 mm could effectively remove the smear layer from the dentin. Dentinal tubule orifices were diminished or partly occluded. With the energy of irradiation increased, the elimination of the intertubular dentin increased; on the other hand, laser with energy beyond 4 W and irradiating distance of 3 mm can also effectively eliminate the smear layer.
Conclusion: Energy of 2-3 W (irradiating distance below 2 mm) and energy of 4-6 W (irradiating distance about 3 mm) are recommended settings with which Er, Cr: YSGG laser can effectively remove the smear layer from the dentin surface. **(Int Chin J Dent 2004; 4: 56-60.)**

Clinical Significance: As a new, valid, and safe method, Er, Cr: YSGG laser selected proper setting can be applied in the clinical practice to remove the smear layer from dentin surface.
Key Words: dentin, Er, Cr: YSGG laser, scanning electron microscopy, smear layer.

Introduction

During the process of restoration for carious tooth, the mechanical preparation of dental cavities will produces a thin smear layer that covers the dentin and enamel walls. The existence of smear layer, which is one of the most important factors to weaken the bond strength between filling materials and the cavity walls, not only affect long-term result of restoration, but also easily result in the producing of secondary caries. Now most dentists adopt the chemical methods to remove this layer, but the operation is complicated and easily do harm to the hard tissue, particularly not well in the hypersensitive tooth. It has been reported recently that erbium, chromium: yttrium-scandium-gallium-garnet laser (Er, Cr: YSGG laser) can validate to eliminate the smear layer. Furthermore, this laser seems have no apparent adverse thermal effect on pulp or hart tissue, and almost doesn't produce any pain and discomfort.[1,2] Otherwise, at present the reports about which settings of power output should be used to effectively remove the smear layer while do not damage the histological structure of the dentin surface have not been seen.

The purpose of this investigation was to compare the morphological changes and elimination of the smear layer on dentin surface after Er, Cr: YSGG laser's irradiation with different power output and irradiating distances, then acquire the most suitable setting to be applied in clinical practice.

Materials and Methods

Twenty-two freshly extracted, noncaries and intact first premolars were used. Dentin slices were prepared by horizontal sectioning through the middle third of the teeth crown using a low speed diamond disk (SH-E, NSK, Tokyo, Japan) and the thickness of the slices was about 1.5 mm. The occlusal surface having been coated by smear layer were experimental surfaces to be treated. The surfaces were washed for 1 minute with running distilled water and dried with air. One slice was randomly selected as the negative control not to be treated and one slice was randomly selected as the positive control to be treated with 37% phosphoric acid gel (ED550104CL, Tongsheng Technology, Inc, Tianjin, P. R. China) for 30 s. Another twenty slices were to be irradiated by laser.

Er, Cr: YSGG laser hydrokinetic system (HKS; Millennium System, Biolase Technology, Inc., San Clemente, CA, USA) was used. This laser system emitted photons at a wavelength of 2.78 μm, pulsed with a duration between 140-200 ms and a repetition rate of 20 Hz. The beam spot size was 0.75 mm. With the use of air 55% and water 35%, dentin surfaces were perpendicularly irradiated by laser. Twenty slices were randomly divided into two groups. The 10 slices of group 1 were irradiated at the distance below 2 mm, and the irradiating distance of another group was beyond 2 mm (about 3 mm). Each specimen of every group was irradiated for 6 s using different power output, viz. 1, 2, 3, 4, and 6 W, and the area to be irradiated was 3x4 mm^2.

The specimens treated by laser and phosphoric acid were dehydrated in the ascending alcohol series, mounted on aluminum slabs, gold coated and examined the morphologic changes of dentin surface with an SEM (SSX-550, Daojing, Tokyo, Japan).

Results

Dentin Morphology of Control Group

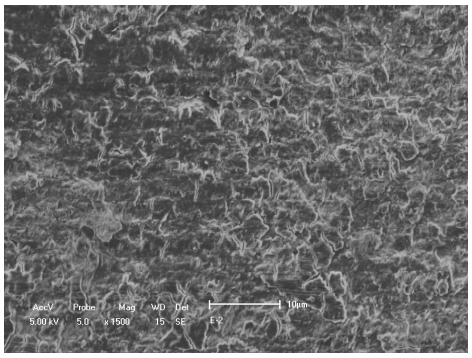
Negative control group showed that the dentin surface was coated with smear layer and the tubular structure was difficult to see (Fig. 1). Positive control group showed comparatively smooth dentin surface. Smear layer was completely removed, and dentinal tubules were clearly visible, the diameter of the tubules was slightly widened. Most orifices were opened, but few of them could be observed the white deposits (Fig. 2).

Dentin Morphology of Group with Irradiation Distance below 2 mm

1 W: Dentin surface showed more irregular than the control group. Part of the smear layer was removed. Dentin tubules exposed in the areas whose smear layer had been removed, and the diameter had no obvious changes (Fig. 3).

2 W: Dentin surface was irregular. Part of the smear layer was removed, most of tubules were opened and a few of them were occluded.

3 W: Most smear layer was removed. Some dentin surfaces were not smooth and showed cascading structure. The diameter of tubules was slightly reduced and part of tubules had deposits. Intertubular dentin seems to ablate more than the peritubular dentin, showing a protrusion of the tubules (Fig. 4).



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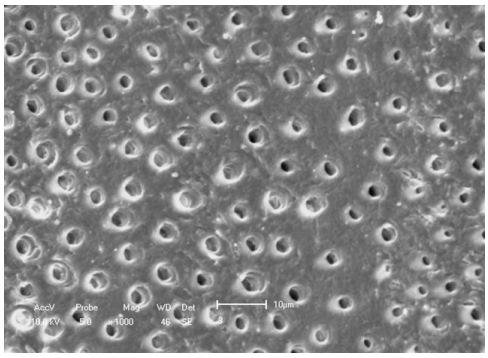

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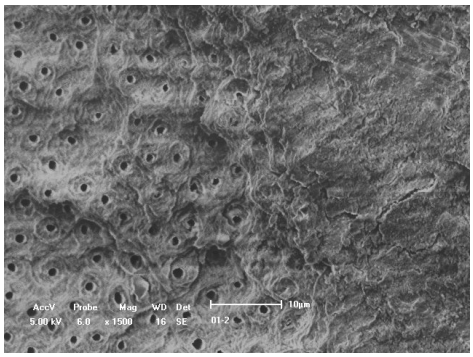
Fig. 1. Negative control group showed the dentin surface was coated with the smear layer.
Fig. 2. Positive control group showed the smear layer was completely removed and most orifices were opened.



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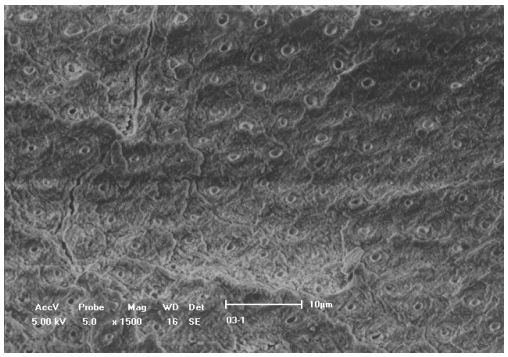

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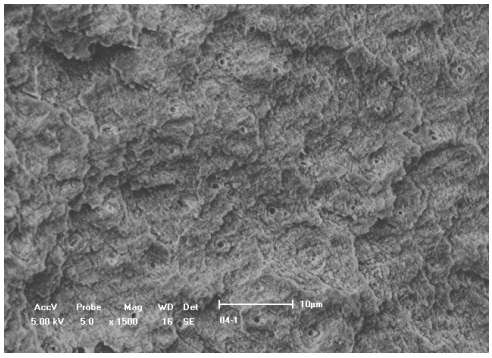
Fig. 3. Specimens irradiated at 1 W below 2 mm showed more irregular appearance and part of the smear layer were removed.
Fig. 4. Specimens irradiated at 3 W below 2 mm showed cascading structure and the diameter of tubules was slightly reduced. Intertubular dentin ablate more than the peritubular dentin.



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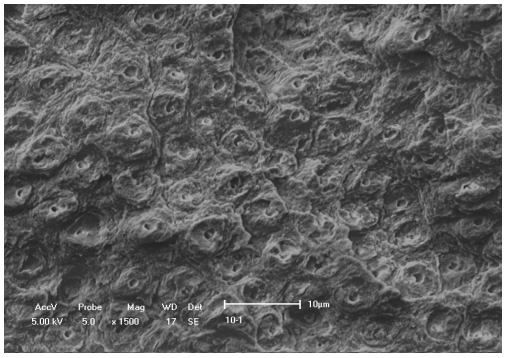

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Fig. 5. Specimens irradiated at 4 W below 2 mm showed more irregular appearance like squama and the diameter was obviously reduced.
Fig. 6. Specimens irradiated at 6W about 3 mm showed most the smear layer was removed and some intertubular dentin melted with peritubular dentin.

4 W: The smear layer was almost completely removed. The dentin surfaces showed more irregular appearance like squama. Most of dentin tubules were exposed and the diameter was obviously reduced (Fig. 5).

6 W: The morphological changes of dentin surface was comparable with the 4 W group, nevertheless, it showed more irregular than it and had microcracks. Intertubular dentin was ablated more than above group.

Dentin Morphology of Group with Irradiation Distance about 3 mm

Most of the smear layer of dentin surface was not removed for specimens that were irradiated at 1-3 W. Part of the smear layer was removed at 4 W and we obtained a relative smooth surface. The dentin tubules were partly exposed and some intertubular dentin melted with peritubular dentin. The morphological changes of dentin surface at 6 W and at 4 W were alike except that most of orifices could be observed occluded (Fig. 6).

Discussion

Smear layer is a loose structure made of dentin debris produced during the cavity preparation progress, metamorphic collagen, saliva, germs and the etc, and the thickness of which is about 0.5-5 μm. The layer can firmly attach the tooth and not be easily removed by flushing and wiping. Most scholars consider it an important way to induce the edge microleakage of restoration removed, furthermore, the elimination of the smear layer can also benefit to decrease the silver-amalgam edge microleakage.[3]

The debris and smear layer removal are thought to have occurred by the Er, Cr: YSGG laser irradiation emitted being absorbed by water, thereby inducing a rapid rise in temperature causing the heated material to be explosively removed.[4] Therefore we observed the morphological changes in dentin surface using different power with the water spray. In our study, when the irradiation distance was controlled below 2 mm, the irradiation with the output power beyond 2 W objected to dentin surface could effectively remove the smear layer. Compared to 4 W and 6 W, dentin surface irradiated at 2 W and 3 W showed more smooth appearance similar to the control group, that is most of dentin tubules were exposed and the orifices did not be occluded or reduced. At 4 W and 6 W, dentin surfaces showed obviously scraggly appearance like squama and clouds, and the intertubular dentin was ablated too much. Our study indicated that when we used lower output power, this laser would exert a simple effect just to remove the smear layer and would not destroy the normal dentin. With the energy of irradiation increased, although the smear layers were almost completely eliminated, the normal dentine beneath the layer would also been partly destroyed or ablated. In fact, most former researcher used Er, Cr: YSGG laser for the ablation of dentin at the energy output of 4-5 W,[2,5] therefore, if our aim is simply to remove the smear layer of dentin, the power output should be controlled between 2 W and 3 W. Moreover, we also found the intertubular dentin seemed to ablate more than the peritubular dentin when high energy is used. The proper reason we presume is that Er, Cr: YSGG laser has an energy wavelength peak of 2.78 μm that corresponds to the absorption coefficient of water and hydroxyapatite which are contained higher in the intertubular dentin.

The laser with the irradiation distance exceed 2 mm will alleviate the ablation effect, and therefore we can regulate the distance between fiber head and tissue to control the effect of ablation.[2] Our observations indicate that the laser with energy above 4 W at the irradiation distance of 3 mm will also effectively

remove the dentin smear layer. However, concerning the distance and project angle is not easily controlled in actual clinical application, we think this method be applicable to the tooth surface with the need of wider irradiation scope and lower accurate degree.

At present, dentists primarily use phosphoric acid to remove the smear layer, but this method can enlarge the diameter of dentin tubules, increase the permeability of tubules, then cause fluxion of the liquid inside which stimulate the pulpo-dentinal complex. Furthermore, this method sometime will aggravate the discomfort of the patients with hypersensitive tooth and even will induce the pulp inflammation. Aim at the above weakness, lasers have characteristics better than and traditional chemistry method which have been accepted by lots of researchers. In recent years, Er, Cr: YSGG laser has already been confirmed to have a series of advantage compared to the other lasers: the roughness of the dentin surface may be obviously increased then consequently enhance the bond strength,[6] dentin can obtain increased acid resistance and somewhat defending capacity for caries,[1,7] this laser does not increase the pulp temperature and 98.5% patients have no discomfort after the clinical application of this laser for cavity preparation.[1,2] Therefore, as a new, validate, and safely methods to do away with the smear layer of dentin surface, this laser have extensive applied foreground. Our observations in vitro proved that energy of 2-3 W (irradiating distance below 2 mm) and energy of 4-6 W (irradiating distance about 3 mm) were proper settings with which Er, Cr: YSGG laser can effectively remove the smear layer from the dentin surface, but considerable additional research should be necessary around the influence of the irradiation on bond strength between materials and tooth.

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