Effect of Er:YAG laser on ultrastructure of dentin by scanning electron microscopy

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Abstract: Laser treatment on dentin has been considered a new method to bring better adhesive effect. The purpose of this study was to observe the ultrastructure of dentin after the treatment of Er:YAG laser by scanning electron microscopy (SEM)and to assess the possibility of laser treatment on dentin to improve the adhesive properties between tooth and restoration. A total of 8 freshly extracted sound human maxillary third molars were prepared according to occlusal veneer. Extracted teeth were treated by Er: YAG laser after tooth preparation. The ultrastructure of dentin was observed by SEM. They were divided into 2 groups, 4 for the control group and 4 for the experimental group. After tooth preparation, the dentin of the experimental group was treated by Er:YAG laser. The specimen were observed by SEM including dentinal tubules, melting and fissure etc. It was observed that in the experiment group there was no smear layer, and the dentinal tubule was clear. Meanwhile, in the control group, there was obvious smear layer in the dentinal tubule therefore the dentinal tubule was not clear. This study suggests that Er: YAG laser treatment on dentin after tooth preparation can remove smear layer in the dentinal tubules, which may improve the adhesive properties between tooth and restoration.

Key words: Er:YAG; dentin; SEM

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Er:YAG 激光对牙本质超微结构作用的电镜观察

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摘 要: 激光照射牙本质被认为是一种改善粘接效果的新方法。此研究的目的是采用电镜观察 Er:YAG 激光照射后牙本质的超微结构, 评价激光处理牙本质以改善牙体组织和修复体之间粘接性能的可行性。共 8 颗新鲜拔除的人上颌第三磨牙按照牙合贴面的要求进行牙体预备,拔除牙齿进行牙体预备后接受激光照射,采用电镜观察牙本质的超微结构。分为两组,4 颗牙齿为对照组,4 颗牙齿为实验组。牙体预备后,对实验组牙齿的牙本质进行 Er:YAG 激光照射。采用电镜观察牙本质小管,熔融和裂隙等情况。对于实验组,观察结果未见玷污层,牙本质小管清晰。同时,对照组可以见到牙本质小

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管内有明显的玷污层,因此牙本质小管不清晰。该研究提示 Er:YAG 激光照射牙本质可以清除牙本质小管内的玷污层,这可能会提高牙体组织和修复体之间的粘接性能。

关键词: Er:YAG; 牙本质; 电镜

0 Introduction

Laser therapy has been applied in dentistry in recent years such as laser caries removal, laser bleaching, laser treatment of dentin hypersensitivity etc[1]. The change tooth surface morphology by laser irradiation may have an influence on subsequent dental therapy. Particularly the effect of laser irradiation on dentin adhesion has been a focus for concern by scholars.

Adhesion between tooth and restoration is an important clinical step which is related with clinical success of restoration. The factors involved with adhesion include the chemical properties of adhesive agent, morphological changes of bonding interface etc [2]. The currrent bonding system includes two kinds of adhesive system: total etching and self-etching. Both of them have drawbacks of their own about dentin bonding interface. The drawback of total etching is that dentin is prone to be permeable by its demineralization and that the dentin cannot be totally filled by adhesive resin [3]. Meanwhile, the drawback of self-etching is that the enamel etching by self-etching adhesive agent cannot be as good as by phosphoric acid[4].

Laser treatment on dentin has been considered a new method to bring better adhesive effect. The wavelength of erbium:yttrium-aluminum-garnet (Er:YAG) laser is 2 940 μm which is happened to be close to the absorption peak of water and hydroxyapatite, therefore Er:YAG laser is suitable for dental hard tissue [5]. After Hibst and Keller[6] had approved the effectiveness of Er:YAG laser on enamel and dentin in 1989, applying Er:YAG laser has been widely recommended to improve the bonding strength[7].

The purpose of this study was to observe the ultrastructure of dentin after the treatment of Er:YAG laser by scanning electron microscopy (SEM)and to assess the possibility of laser treatment on dentin to improve the adhesive properties between tooth and restoration. This study may support the feasibility of laser treatment on dentin before applying bonding system and may provide theoretical basis for the application of laser treatment on dentin.

1 Materials and methods

1.1 The samples

Eight freshly extracted sound human maxillary third molars were chosen upon the approval of Ethical Committee of Stomatology Hospital of Jilin University. All of the teeth were similar with dimension and form, and were stored in 0.1% thymol solution (Thymol crystal, Jiangxi Herb Pharmaceutical Co Ltd), replaced once a day.

1.2 Tooth preparation

This study referred to the method of tooth preparation of Pascal Magne′s study on CAD/CAM manufactured occlusal veneers[8](Fig.1). The exposed dentin was in the center, while enamel

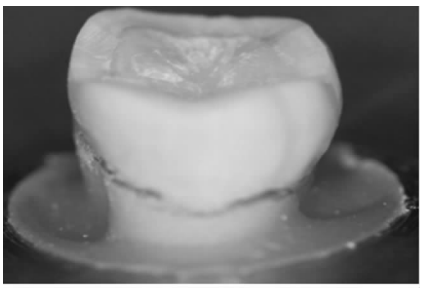


Fig.1 Prepared tooth with inclination of cusp maintained, pencil line presenting cementum-enamel junction. The shown tooth was without laser treatment on dentin

was peripheral. Each tooth after preparation was observed to confirm with no pulp exposure, crack or fracture.

1.3 Grouping

After tooth preparation, a total of 8 freshly extracted sound human maxillary third molars were divided into 2 groups, 4 for the control group and 4 for the experimental group.

1.4 Laser treatment

Laser treatment was applied to the teeth of the experimental group. The laser treatment method was as follows: laser device was AT Fidelis (Fotona Medical Lasers), Er:YAG was chosen, along with contact handpiece R14, a sapphire tip (72 856, 12 mm long, 0.8–1.3 mm diameter). The pulse width was chosen as 100 μs (medium–short pulse, MSP). According to the laser manufacturer, the parameters were set at 120 mJ, 10 Hz, 1.20 W with water spray at 6. The distance from the sapphire tip to the dentin surface was 1 mm. The laser beam moved uniformly according to unified direction above the whole dentin surface.

1.5 SEM analysis

All of the specimens were dried and sputter–coated (Q150TS, QUORUM) with a thin layer of gold–palladium under high–vacumm conditions, and finally examined using the scanning electron microscope (XL–30, FEI) with a magnification of ×50–4000. All of the specimens were obseved and compared with surface morphology characteristics of dentin, such as surface roughness, smear layer, dentin tubule, dentin melting and fissures.

2 Results

2.1 Control group

In the tooth with no laser treatment on dentin, dentin surface was overlapped with smear layer, which was slight undulate with irregular dentin debris. Besides, much of the dentinal tubules were closed by smear layer(Fig.2).

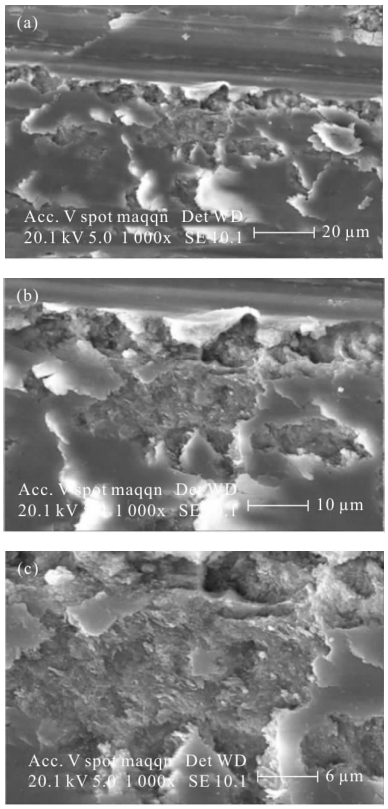
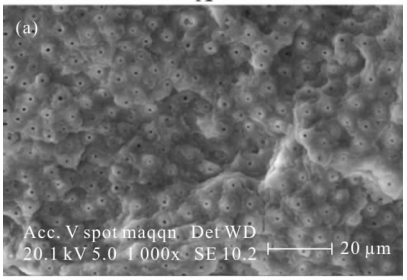


Fig.2 SEM image of dentin surface in control group. (a)–(c) showed dentin surface with no laser treatment at ×1 000, 2 000 and 4 000 magnification. It was shown that dentin surface was overlapped with smear layer and much of the dentinal tubules were closed by smear layer

2.2 Experimental group

In the tooth with laser treatment on dentin, there was no smear layer, therefore dentin surface was clean but with a rough, irregular, scaly appearance. Open dentinal tubules can be found in most area, while extremely rare ones were closed with tube plug. Peritubular dentin was more prominent than inter–tubular dentin(Fig.3).



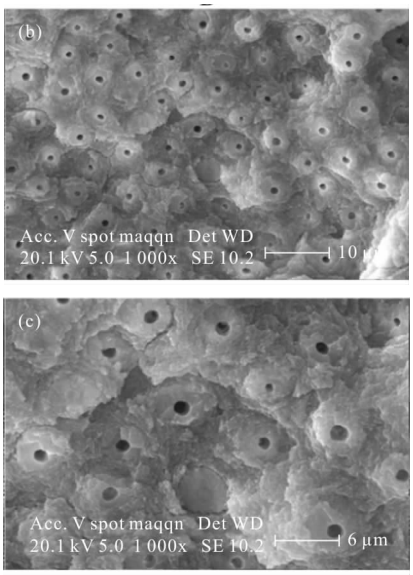


Fig.3 SEM image of dentin surface in experimental group. (a)–(c) showed dentin surface with laser treatment at ×1 000, 2 000 and 4 000 magnification. It was showed that dentin surface was rough and clean with no smear layer and open dentinal tubules can be found in most area

3 Discussion

This study showed that morphological characteristics of dentin with laser treatment was totally different from dentin with no laser treatment. There was no smear layer in dentinal tubule after laser treatment, meanwhile, the dentin in control group has obvious smear layer which led to an unclear dentinal tubule condition.

During the procedure of tooth preparation, smear layer will be formed with traditional diamond bur. Smear layer can lead to microleakage and affect the bonding strength. Currently, acid–etching with 37% phosphoric acid has been a common method to remove smear layer, especially for enamel[9–12]. However, it is not effective enough to dentin because of its composition structure and constituent. When laser treatment was applied to dentin, the energy was absorbed by water and hydroxyapatite and evaporated rapidly, creating the effect of micro explosion, which can tattered smear layer and make it fly away from dentin. Meanwhile, laser treatment on dentin cause small hot and mechanical damage to dentin since residual energy is small and most thermal energy has been transformed into motion energy [6, 13–15]. Therefore, in the tooth with laser treatment on dentin, dentin surface was clean with no smear layer but with open dentinal tubules.

In addition, after laser treatment, dentin surface was with a rough, irregular, scaly appearance, and peritubular dentin was more prominent than inter–tubular dentin[16–17]. The main reason for this phenomenon is that different dentin structure has different water content. The water content of inter–tubular dentin is more than that of peritubular dentin, therefore, when they received same laser energy, inter–tubular dentin was removed more than peritubular dentin. Consequently, it made peritubular dentin more prominent and like a sleeve.

Rough surface of dentin, open dentin tubule and prominent peritubular dentin hinted that laser treatment on dentin may increase the bonding surface and may improve the bonding strength between dentin and restoration [18]. However, the effectiveness of laser treatment on dentin is controversial. Some scholars supported the etching ability of laser treatment on dentin[19–20], considered that laser preparation and acid etching could improve microleakage and guarantee better marginal integrity[19], and some scholars also affirmed that laser treatment on dentin could improved shear/tensile bond strengths between dentin and self–etching adhesive systems[20–21]. Meanwhile, other scholars thought this method is invalid[22–23].

The results of this study showed that Er:YAG laser treatment on dentin after tooth preparation can remove smear layer in the dentinal tubules, which may improve the adhesive properties

between tooth and restoration. This study provided an experimental basis for the application of Er: YAG laser on dentin before applying bonding system, and further, supply a thought of research for enhancing bonding strength.

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