The experimental study for the effect of tooth-brushing on the laser irradiated dentin surface

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국문초록

ND-YAG 레이저가 조사된 상아질 표면에 칫솔에 의한 기계적 마모가 미치는 영향에 대한 실험적 연구

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치근부 민감성 (hypersensitivity)은 부분적으로 치근면에서의 개방된 상아세관이 존재하는 것에 기인한다고 생각되며 이러한 치근부의 개방된 상아세관은 치경부 병소 (cervical lesion)에 주로 존재하는데 이는 칫솔질에 의한 마모 (toothbrush abrasion), 화학적 침식 (chemical erosion), 또는 abfraction 등의 결과로 나타난다고 한다. 이미 Nd-YAG 레이저를 이용한 실험에서 레이저를 조사한 상아질 표면의 상아 세관 구경이 감소되고 상아세관의 폐쇄가 많이 증가되는 양상을 관찰한 바 있다. 이 실험의 목적은 고출력레이저인 Nd-YAG 레이저를 이용한 상아질표면처치의 임상사용가능성을 좀 더 상세히 평가하기위해 상아질에 레이저를 처리한 후 기계적으로 마모 시킨 경우 상아질 표면의 변화를 관찰하는 것이다. 50개의 발치된 치아의 상아질을 노출시켜 표면을 연마한 후 대조군에서는 37% 인산으로 산부식하여 상아 세관을 노출시킨 후 레이저를 조사하였고, 실험군에서는 대조군과 같은 조건으로 산과 레이저로 처리된 상아질 표면을 15, 45, 90 그리고 180분 동안 전동 칫솔로 기계적으로 마모시켜 그 표면을 주사전자현미경으로 관찰한 결과, 대조군, 칫솔질을 15, 45분간 시행한 실험군에서는 상아 세관 입구가 10% 이내에서 노출되었고 90 그리고 180분간 칫솔질을 시행한 실험군에서는 45 그리고 48%의 상아세관 입구의 노출이 관찰 되었다. 그러므로 Nd-YAG 레이저의 조사는 상아질 표면에서 축적 시간이 45분 이상에서 90분 이하인 기계적 마모에 의한 상아 세관 입구의 노출을 억제할 수 있을 것이라 사료된다.

주요어 : 상아질, Nd-YAG 레이저, 칫솔질, 도말층

Ⅰ. Introduction

Dentin hypersensitivity is one of the most painful and least predictably treated chronic conditions in dentistry. It has been thought to be partially caused by the opening of dentinal tubules. If the exposed dentin surfaces and the number of opened dentinal tubules are increased, the patient feels more discomfort, especially during air blast, mechanical stimulation, thermal extremes or intense osmotic stimulation. In order to decrease the hypersensitivity, various attempts at blocking the dentinal tubules or changing the content of the dentinal tubules have taken place. Several medicaments and materials have been recommended to block the dentinal tubules. However, most of them have proved to be ineffective or have a short duration.

Dederich *et al.*[1] used the Nd:YAG laser to make the dentinal walls of the root canals smooth due to melting and recrystalizing of the dentinal surface.

Harvey *et al.*[2] demonstrated that the treated dentin with Nd:YAG laser appeared to have melt-

ed the surface because of spherical areas seen in the SEM.

Renton-Harper *et al.*[3] demonstrated that treatment of dentin with an Nd:YAG laser showed significant effectiveness in reducing dentin hypersensitivity.

In a clinical study, Nd:YAG laser reduced dentin hypersensitivity to air stimulation by 65% and to mechanical stimulation by 72%[4].

Nd:YAG laser has been reported to cause melting of dentin and closure of exposed dentinal tubules without dentin surface cracking. The sealing depth of Nd:YAG laser on human dentinal tubules was approximately 4 microns[5].

Brushing dentin surfaces with dentifrice produced rough surfaces to abrasion of the enamel and the dentin at a rate of about 0.1 and 1.5 microns/min[6].

The aim of the present study was to evaluate, by scanning electron microscopy, the effect of the tooth-brushing with dentifrice on Nd:YAG laser irradiated human dentin.

Ⅱ. Materials and Methods

Fifty intact molar teeth stored in distilled water (4℃) were used in this study. Prior to their preparation, soft tissue and debris were removed using an ultrasonic scaler. Sound coronal dentin was exposed with high speed handpiece and diamond bur. Samples were randomly divided into 5 groups. Samples were embedded in an orthodontic resin block, and the exposed dentin surfaces were polished with 4000 grit abrasive paper.

In the control group, the exposed dentin surfaces were etched with 37% phosphoric acid (3M. Co. St. Paul, MN, U.S.A.) for 15 seconds and rinsed with distilled water for 20 seconds. Then the dry etched dentin surfaces were evenly irradiated with an Nd:YAG laser (DYL-3000EN, SAIT Co. Korea) set in 50 mJ/pulse, 10 pulses/sec for 10 seconds using a 300 ㎛ optic fiber held 1 mm from the surface .

In the experimental groups, the etching and lasing procedures were the same as in the control group but the specimens were subsequently brushed for 15, 45, 90 and 180 minutes with an electronic toothbrush(Braun Co. U.S.A.) using a slurry made by mixing 1 gram of dentifrice (Perio toothpaste LG. Co. Korea) with 5 cc of saline under a vertical load of 120 grams on the toothbrush. The slurry under the brush was replaced every 3 minutes.

After treatment and rinsing with saline, all specimens were stored in the saline, dried at the dry oven (80℃), gold-coated in a high resolution sputter coater (E5400, Biorad, U.S.A.) and examined in a scanning electron microscope (JEOL, JSM-840A, Tokyo, Japan).

Five sites per each specimen were observed and photographed. The number of open dentinal tubules divided by the total number of tubules per unit area were counted and the state of remaining smear layer were evaluated in a uniformly rectangular area (16×22 ㎛^{2} per each site). To isolate the group or groups that differ from the others a multiple comparison procedure (Student-Newman-Keuls Method) was used.

Ⅲ. Results

Various morphologic changes were observed on the lased and tooth-brushed dentin surfaces in the specimens.

Detailed results of the number of opened dentinal tubules were shown in the Table 1.

There was no statistically significant difference between the control and the experimental groups brushed for 15 minutes or 45 minutes ($P > 0.05$). There was a statistically significant difference between the experimental group brushed for 45 minutes and the experimental group brushed for 90 minutes ($P < 0.05$).

There was a slight difference between the 90 minutes and the 180 minutes, but it was not statistically significant ($P > 0.05$).

In the controls and experimental groups brushed for 45 minute, a smear layer covered most of the surface of the specimens. Few dentinal tubule orifices were seen(Figs. 1 and 2).

In 90 and 180 minutes experimental groups, moderate patchy smear layer was observed. Many

Table 1. Numbers of the open dentinal tubules

Group	No. of sites	Number of the specimens										Sum	Ratio of open tubules*
		1	2	3	4	5	6	7	8	9	10		
Control group	1	0/11	0/10	0/12	0/9	0/11	0/10	0/10	1/12	1/11	1/11	15/359	4%[a]
	2	1/6	0/5	0/7	1/5	0/6	0/6	1/7	0/7	1/9	0/7		
	3	1/5	0/5	0/6	0/7	1/7	0/5	0/5	1/6	0/5	0/6		
	4	0/5	0/5	1/6	0/6	1/8	0/5	0/9	0/6	0/6	0/7		
	5	0/7	1/6	0/6	0/6	1/8	0/8	1/5	0/5	0/7	0/9		
Experimental gourp (15 minutes)	1	0/8	1/9	1/14	1/9	2/10	0/7	1/6	0/8	1/9	0/9	22/442	5%[a]
	2	0/6	0/11	0/8	1/10	0/11	0/8	0/7	0/9	1/7	1/9		
	3	0/13	0/10	0/9	1/9	0/8	2/6	0/11	0/9	1/10	1/11		
	4	1/11	0/7	0/6	0/11	0/7	1/10	0/8	0/9	1/9	1/6		
	5	1/10	1/11	1/9	0/8	0/10	0/7	0/6	0/11	0/8	0/7		
Experimental group (45 minutes)	1	0/10	0/12	0/9	0/10	1/11	0/12	2/10	0/12	1/11	0/10	23/385	6%[a]
	2	0/7	0/7	1/5	0/7	0/9	0/5	0/6	1/6	1/7	0/5		
	3	2/7	0/6	1/7	0/8	1/5	1/6	0/5	0/5	1/6	0/5		
	4	0/9	2/5	1/6	0/8	0/6	1/9	0/5	1/5	1/8	0/6		
	5	1/10	0/8	0/8	0/10	1/7	0/11	1/8	0/7	1/7	0/11		
Experimental group (90 minutes)	1	3/6	4/6	5/9	4/9	3/5	6/10	4/9	2/6	5/9	5/11	151/335	45%[b]
	2	2/9	2/5	2/5	3/8	3/7	2/5	4/7	2/5	2/5	2/5		
	3	1/7	2/5	2/5	3/8	3/7	1/5	4/8	3/5	2/6	2/5		
	4	2/5	3/5	2/7	3/5	3/6	6/9	4/10	3/7	3/7	5/8		
	5	3/6	4/6	2/6	2/5	3/6	3/6	5/10	2/5	4/9	2/5		
Experimental group (180 minutes)	1	4/9	2/5	5/8	2/6	5/9	6/11	5/10	3/9	2/8	5/8	190/403	48%[b]
	2	4/10	2/8	6/9	4/7	3/7	6/9	4/9	3/0	2/6	2/5		
	3	3/5	2/5	5/11	4/9	3/6	2/5	4/11	5/11	6/12	2/8		
	4	3/5	3/5	4/7	3/6	5/7	6/7	4/10	3/8	6/10	2/5		
	5	4/8	3/7	5/10	4/5	3/8	5/13	4/8	4/9	6/14	2/5		

* the number of the open dentinal tubules/ number of the dentinal tubules in the observed area

[a,b] Groups identified by different superscript letters are significantly different ($P<0.05$)

dentinal tubule orifices were visible(Figs. 3 and 4).

Ⅳ. Discussion

Cervical abrasion is related with tooth-brushing procedures. Clinical evidence demonstrates that an excessive use of dentifrice habitually placed, undiluted, on the same area of the mouth, may produce cervical abrasion[7].

Some cervical abrasive lesions may be filled with restorative material and others may be treated with desensitizing agents and materials. To treat dentin hypersensitivity, several medicaments and materials are recommended to block the dentinal tubules. The importance of occluding the dentinal tubules in certain clinical conditions is well established. The aim of therapy for sensitive teeth is to either reduce the number of open tubules or decrease their diameter [8].

Brushing with a dentifrice containing calcium

hydrogen phosphate as an abrasive caused most of the dentinal tubules to open[6]. The patency of dentinal tubules is thought to induce dentin hypersensitivity. Brushing without a dentifrice, on the other hand, resulted in occlusion of the dentinal tubules with organic pellicle-containing minerals[9]. Furthermore, abrasion did not occur; however, no bacterial plaque or dental calculus were retained on such surfaces. Such occluded tubules, which were distributed over the entire dentin surfaces, would likely prevent hypersensitivity. Such organic-mineral materials occluding the tubules can be derived from saliva and brushed on dentin by the brushing without using dentifrice. Kuroiwa et al. suggested that use of a non-abrasive dentifrice would prevent or reduce dentin hypersensitivity in the cervical regions[9]. Remizov *et al.* demonstrated that no abrasive effects were detected when brushing normal teeth with water. The rate of enamel and dentin abrasion caused by tooth powder or toothpaste suspensions depended on the shape of bristle cut and particularly on the toothbrush roughness[10]. However, many people have used dentifrice everyday without causing abrasion. They may brush for shorter times and/or use less force than patients who experience cervical abrasion.

In Kodaka's study[6], automatic brushing with and without a commercial dentifrice containing calcium hydrogen phosphate as an abrasive, was performed on ground surfaces of sound enamel and dentin in human young premolar teeth, with a load of about 120 g for 10 minutes in vitro [6].

Brushing with abrasive dentifrice caused rough surfaces to appear and a rate of abrasion of the enamel and the dentin of 0.1 and 1.5 microns/min, respectively. However, when brushed with only distilled water, the enamel surfaces remained intact while the dentin surfaces became smoother. Therefore, the current study adopted the use of automatic brushing with a commercial dentifrice and the pressure on the toothbrush that was same as in the Kodaka's study.

The use of the Nd:YAG laser irradiation produced a sealing of exposed tubules, however, this surface seal was removed in about 3 minutes by brushing with abrasive dentifrice[6]. In the current study, brushing the laser-treated surfaces for 0, 15 and 45 minutes failed to open tubules orifices (Table 1). Only after brushing for 90 min was there a significant increase in open tubules. Since many patients only brush their teeth for 1 min, once a day, the result suggests that Nd:YAG laser treatment for dentin hypersensitivity may last at least 3 months.

In Liu's study[12], specimens were brushed with an electric toothbrush for 30 minutes, without any dentifrice. This is thought to be different from the usual clinical situation because most people use dentifrice during tooth-brushing. Therefore, an abrasive-containing dentifrice was used in this study for tooth-brushing and the brushing time was determined as the following. If the 3 surfaces of the 6 parts (upper and lower anterior, right upper and lower posterior and left upper and lower posterior teeth) were brushed for 3 minutes brushing, brushing time per surfaces of each part will be estimated to be 10 seconds. Therefore, accumulated brushing time per surface of 1, 3, 6 and 12 months would be about 15, 45, 90 and 180 minutes.

The use of He:Ne+Nd:YAG treatment was reported to reduce dentin sensitivity to air by 58 percent and to mechanical stimulation by 61 percent. All teeth remained vital after laser treatment, with no adverse reactions or complications[4]. Clinical studies showed that Nd:YAG laser can reduce dentin hypersensitivity to air by 65% and mechanical stimulation by 72% without pulpal damage during a 3-month evaluation[11]. According to the results of that study, a 3 month recall check and Nd:YAG laser treatment can be recommended to patients with dentin hypersensitivity.

Further clinical studies using Nd:YAG laser and other agents combined with it to intensify the efficacy of treatment of dentin hypersensitivity are indicated.

Ⅴ. Conclusions

In this experiment, Nd-YAG laser irradiation of acid-etched human dentin produced occlusion of

the tubules orifices. Brushing these treated surfaces 15 or 45 min did not open any tubules. After 90 and 180 mintues of toothbursching, there was statistically a significant ($P<0.05$) increase in the numbers of open dentinal tubules in comparison with the control, or 15 and 45 min experimental group. There was no statistically significant difference between the 90 and 180 experimental groups. Nd-YAG laser-irradiation to dentin surfaces may be effective to keep dentinal tubules closed for between 45 and 90 days.

References

1. Dederich DN. Scanning electron microscopic analysis of canal wall dentin following neodymium-yttrium-aluminum-garnet laser irradiation. Journal of Endodontics 1984;10: 428-431.
2. Harvey W, Elliot A, Shahid A, Joseph T and Walsh Jr. The effect of lasers on dental hard tissue. Journal of Ameriacan Dental Association 1993;124:65-70.
3. Renton-Harper P and Midda M. Nd:YAG laser treatment of dentinal hypersensitivity. British Dental Journal 1992;172:13-16.
4. Gelskev SC. The effectiveness of the Nd:YAG laser in the treatment of dental hypersensitivity. Journal of Canadian Dental Association 1993;59: 377-378, 383-386.
5. Liu HC. Sealing depth of Nd:YAG laser on human dentinal tubules. Journal of Endodontics 1997;23: 691-693.
6. Kodaka T. Scanning laser microscopic surface profiles of human enamel and dentin after brushing with abrasive dentifrice in vitro. Scanning Microscopy 1993;7: 247-254.
7. Radentz WH. A survey of factors possibly associated with cervical abrasion of tooth surface. Journal of Periodontology 1976;47: 148-154.
8. Addy M and Dowell P. Dentin hypersensitivity. A review. II. Clinical and vitro evaluation of treatment agents. Journal of Clinical Periodontology 1983;10: 351-361.
9. Kuroiwa M. Dentin hypersensitivity. Occlusion of dentinal tubules by brushing with and without an abrasive dentifrice. Journal of Periodontology 1994;65: 291-296.
10. Remizov SM and Pruzhanskii Liu The effect of toothbrushes on human dental enamel and dentin wear. Stomatologiia(Mosk) 1990;4: 4-6.
11. Lan WH and Liu HC. Treatment of dentin hypersensitivity by Nd:YAG laser. Journal of Clinical Laser Medicine and Surgery 1996;14: 89-92.
12. Lan WH. The combined occluding effect of sodium fluoride varnish and Nd:YAG laser irradiation on human dentinal tubules. Journal of Endodontics 1999;25: 424-442.

Explanation of Figures

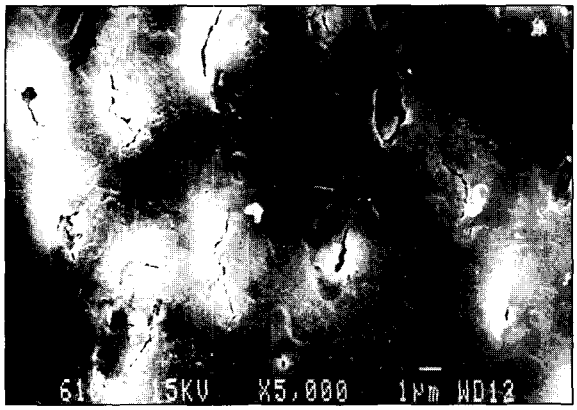

Fig. 1. Control group showing that most of the orifices of dentinal tubules were closed. ×5,000

Fig. 2. In the experimental group brushed for 45 minutes, almost all dentinal orifices were still occluded and the smear layer covered the dentin surface. × 5,000

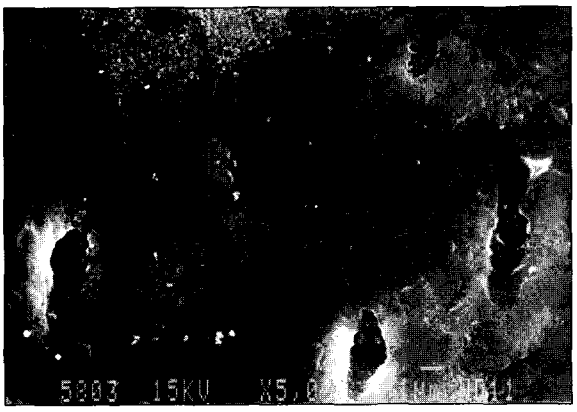

Fig. 3. In experimental groups brushed for 90 minutes, only moderate patchy smear layer was observed. Many open tubules were visible. ×5,000

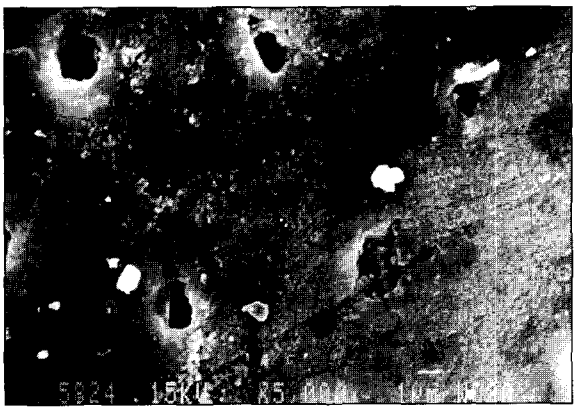

Fig. 4. In the experimental group brushed for 180 minutes, most of the smear layer was removed and many tubule orifices were open. ×5,000