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Effect of 1320 nm Nd:YAG Laser-Activated Irrigation on Sealer Penetration in Curved Root Canals

만곡 근관에서 1320nm Nd:YAG 레이저를 이용한 근관 세척 방법에 따른 근관 봉합재의 침투도에 관한 연구

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논문제목: Effect of 1320 nm Nd:YAG laser-activated irrigation on sealer penetration in curved root canals

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–Abstract–

Effect of 1320 nm Nd:YAG Laser–Activated Irrigation on Sealer Penetration in Curved Root Canals

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Introduction

The purpose of this study was to investigate the efficacy of laser–activated irrigation (LAI) of 1320 nm neodymium–doped: yttrium–aluminum–garnet (Nd:YAG) laser on sealer penetration into dentinal tubules in the presence of 5.25% sodium hypochlorite (NaOCl) or 17% ethylenediaminetetraacetic acid (EDTA) solution.

Materials and Methods

Sixty three curved root canals (20–40°) from extracted human molars were prepared to #30/.06 (ProFile, Dentsply Tulsa Dental, Tulsa, OK, USA) with 5.25% NaOCl irrigation.

Teeth were divided into 4 experimental groups (n = 15) as follows: group N, 5.25% NaOCl final flush without LAI; group E, 17% EDTA final flush without LAI; group NL, 5.25% NaOCl with LAI; group EL, 17% EDTA with LAI. In all experimental groups, the laser fiber was inserted and withdrawn 4 times for 5 seconds each, with 10-second intervals between each. NaOCl (3 ml) in group N and NL or EDTA (3 ml) flushing in group E and EL was performed during intervals. Three teeth which were not irrigated during preparation were used as negative controls.

Teeth were obturated with gutta-percha and fluorescent-labeled AH Plus sealer (Dentsply DeTrey, Konstanz, Germany) by using the continuous wave of condensation technique. Transverse sections at 2 and 5 mm from root apex were examined with confocal laser scanning microscopy, and the percentage of sealer penetration into dentinal tubules was measured.

Results

Groups E, NL, and EL showed higher percentage of sealer penetration than group N ($P < .05$). With NaOCl solution as irrigant, LAI (group NL) resulted in significantly higher amount of sealer penetration than nonactivated counterpart group (group N) in both 2 and 5 mm levels ($P < .05$). In the presence of EDTA solution, the average percentage was also higher in laser-activated group (group EL) than in nonactivated group (group E) at both levels, but the difference was not statistically significant ($P > .05$).

Conclusions

1320 nm Nd:YAG laser activation with 5.25% NaOCl solution increased sealer penetration around the canal wall. LAI with 17% EDTA also showed higher sealer penetration than syringe irrigation but the difference was not significant. With the current setting, LAI with 5.25% NaOCl solution prior to root canal obturation might be beneficial in enhancing sealer penetration in curved canals.

Keywords: EDTA, CLSM, laser-activated irrigation, NaOCl, Nd:YAG, sealer penetration

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VIII. 국문초록

I. Introduction

Removal of necrotic pulp tissue, dentin debris, and residual microorganisms from the root canal system is a prerequisite for endodontic success (1, 2). After root canal instrumentation, a smear layer containing inorganic dentin debris and organic substances is formed (3). This smear layer might harbor bacteria and could inhibit the penetration of root canal irrigants and/or intracanal medicaments into the dentinal tubules (4, 5).

Use of chelating agent such as ethylenediaminetetraacetic acid (EDTA) has been advocated for removal of inorganic components of the smear layer that are not effectively removed by sodium hypochlorite (NaOCl) irrigation alone (3, 6). The majority of studies that evaluated the efficacy of EDTA application on the smear layer removal were carried out in single-rooted teeth with straight canal or in sectioned dentin (6-8). Neither of them could simulate clinical situations such as the apical portion of the curved root canals in molars, which is the challenging part of debridement.

In this regard, Moon et al (9) evaluated the effect of final irrigation regimen in curved root canal by measuring the extent of sealer penetration into the dentinal tubules. They showed that 1-minute application of EDTA for final irrigation resulted in greater penetration in coronal part of the canal than that of NaOCl irrigation alone. However, there was no significant difference in depth of penetration in apical part of the canal, although final irrigation of EDTA resulted in broader sealer penetration around the root canal wall. This implies that future studies should focus more on finding effective debridement methods in apical portion of the curved root canals. In addition, this research method can be used for evaluation of the efficacy of final irrigation in removing smear layer because this dentin debris-containing structure can prevent sealer from penetrating into the tubules (10-12).

Recently, laser-activated irrigation (LAI) by mid-infrared erbium lasers has been introduced as an agitation method for smear layer removal (13-18). Use of neodymium-doped: yttrium-aluminum-garnet (Nd:YAG) laser with 1064 nm wavelength was also reported to enhance cleansing of the root canals compared to NaOCl irrigation (19, 20). It is presumed that the effect of smear layer removal has a close linkage with absorption coefficient in water of certain type of laser (13). Because 1320 nm Nd:YAG laser is more strongly absorbed in water than 1064 nm Nd:YAG laser (21, 22), it is assumed that 1320 nm Nd:YAG laser might be more effective in smear layer removal than 1064 nm Nd:YAG laser. However, LAI efficacy on the smear layer removal or sealer penetration into the dentinal tubules for 1320 nm Nd:YAG laser in the apical portion of the curved canal has not been studied so far.

Therefore, the purpose of this study was to investigate the effect of 1320 nm Nd:YAG laser activation with different final irrigation regimens on the sealer penetration into dentinal tubules in the curved root canals.

II. Materials and methods

Sample preparation

Sixty three extracted human molars that had mesiobuccal or distobuccal roots of maxillary molars and mesial roots of mandibular molars with the root curvature ranged between 20–40º with fully formed apices were used. The teeth were prepared as described in the previous study (9). Each tooth was decoronated to a 12 mm length. Access cavities were made, and a #10 K-file (Dentsply Maillefer, Zurich, Switzerland) was inserted to confirm the patency. Working length was established by subtracting 1 mm from the length to the apical foramen.

Radiographs of teeth into which #15 K-files were inserted in the canals were used, and Schneider method (23) was applied to measure the canal curvature (Fig. 1). Those teeth with root canal curvatures between 20-40° were selected.

The canals were prepared by a crown-down technique using ProFile (Dentsply Tulsa Dental, Tulsa, OK, USA) rotary instruments to a size 30 and 0.06 taper to working length. The canals were irrigated with 1 ml of 5.25% NaOCl between successive files during instrumentation. All irrigation in the present study was performed using 30-gauge irrigation needles (Vista-Probe; Vista Dental, Racine, WI, USA), and they were used with an up-and-down motion to 1-2 mm short of the working length. Three teeth that were not irrigated during preparation were used as negative controls.

Laser application

A Nd:YAG laser with a wavelength of 1320 nm (Slimlift MPX; B&B systems, Seoul, Korea) was used for laser irradiation. The laser was used with pulse energies of 150 mJ at 10 Hz (average power, 1.5 W) and was delivered with a 200 μm flexible endodontic fiber. During irradiation, the laser fiber was used with up-and-down motion and kept 3 mm away from the root apex.

Irrigation protocols

After the chemomechanical preparation, the teeth were randomly divided into four experimental groups according to the final irrigation protocols.

Group N (n = 15): the laser fiber was inserted but not activated in the presence of 5.25% NaOCl solution. Laser fiber was inserted and withdrawn 4 times for 5 seconds each, with 10-second intervals between each. 5.25% NaOCl (3 ml) flushing was performed during intervals.

Group E (n = 15): Samples were treated as in group N, with 17% EDTA solution as an irrigant.

Group NL (n = 15): Samples were treated as in group N, with laser activation.

Group EL (n = 15): Samples were treated as in group E, with laser activation.

Root canal obturation

After the final irrigation, each canal of all experimental groups was flushed with 5 ml of distilled water and then dried with paper points. Then all canals including negative control group were obturated with gutta-percha and AH Plus sealer (Dentsply DeTrey, Konstanz, Germany) by using the continuous wave of condensation technique (24). For fluorescence under confocal laser scanning microscopy (CLSM), sealer was mixed with 0.1% fluorescent rhodamine B isothiocyanate (Sigma-Aldrich, St Louis, MO, USA). The labeled sealer was thoroughly applied into the canal to the level of 1 mm short of the working length with #30 lentulo spirals (25). After the medium-sized gutta-percha cone tip was adjusted, the cone was lightly coated with the sealer and placed into the canal. A heated plugger (SuperEndo-α^2; B&L Biotech, Ansan, Korea) was activated and inserted to a point 4–5 mm short of working length. Next, sustained push was carried out in an inactivated state for approximately 10 seconds, and the coronal portion of the gutta-percha cone was immediately removed in an activated state. The coronal portion of the canal was backfilled by using an injectable gutta-percha system (SuperEndo-β; B&L Biotech), and then gutta-percha was compacted with Obtura S-Kondenser (Obtura Corporation, Fenton, MO, USA). The access cavities were sealed with Caviton (GC Corp., Tokyo, Japan). Subsequently, the teeth were kept in incubator at 37℃ and 100% humidity for 24 hours to allow the sealers to set.

CLSM investigation

The samples were prepared and evaluated with CLSM (Zeiss LSM-Pascal; Carl Zeiss, Göttingen, Germany). Each tooth was embedded in an acrylic block, and 500 μm-thick transverse sections of each mesiobuccal or distobuccal root were obtained with a slow-speed, water-cooled diamond saw (Isomet Low Speed Saw; Buehler, Lake Bluff, IL, USA) at 2 and 5 mm from the root apex.

The samples were then mounted on glass slides and examined by using CLSM with excitation by a He/Ne G laser (543 nm). The samples were observed using a 2.5X (numerical aperture, 0.075) oil lens with additional zooms of 2X (total magnification, 50X). The detector gain was set in the range of 740–760 and the observed layer was determined 10 μm below the specimen surface (26). One sample was observed using a 20X (numerical aperture, 0.5) oil lens with additional zooms of 2X (total magnification, 400X) for detailed view of dye-labeled sealer penetration into dentinal tubules. The images were acquired and analyzed using Zeiss LSM Image Examiner software (Carl Zeiss). The percentage of the sealer penetration was determined by the modified method described by Gharib et al (27) and Moon et al (9). In each image, the circumference of the root canal wall was measured with the measuring tool software (Fig. 2). Next, areas along the canal circumference into which the sealer penetrated the dentinal tubules with any distance were outlined and measured. The percentage of any canal wall where sealer had penetrated was calculated by dividing outlined length by the canal circumference.

Statistical analysis

For overall comparisons, a nonparametric test was performed using Kruskal–Wallis analysis, and a series of Mann–Whitney tests were used for multiple comparisons. Differences in the percentage of sealer penetration between 2 mm and 5 mm levels for each group were analyzed with Wilcoxon signed rank sum test. The level of significance was set at 5%.

III. Results

A consistent fluorescent layer of sealer around the root canal wall was observed in all sections. A CLSM image with high magnification (400X) showed the detailed view of fluorescent dye–labeled sealer penetrating into dentinal tubules (Fig. 3).

The results of the percentage of sealer penetration into dentinal tubules are reported in Table 1 and in Figure 4 and representative pictures from each group are shown in Figure 5. The mean percentage of sealer penetration at 2 mm level was group N, 16.0%; group E, 22.3%; group NL, 35.3%; group EL, 40.0%, and at 5 mm level; group N, 34.9%; group E, 57.2%; group NL, 68.5%; group EL, 76.6%. The samples in the negative control showed no sealer penetration into the dentinal tubules.

The Kruskal-Wallis tests showed a statistical difference among the final irrigation protocols at each level (2 mm level: $p = .003$, 5 mm level: $p = .001$). Mann-Whitney tests revealed that group E, NL and EL resulted in significantly higher percentage of sealer penetration than group N at both 2 mm and 5 mm level ($P < .05$). When NaOCl was used as irrigating solution, laser-activated group (group NL) showed significantly higher penetration than nonactivated group (group N) at both levels ($P < .05$). In the presence of EDTA solution, the average percentage was also higher in laser-activated group (group EL) than in nonactivated group (group E) at both levels, but the difference was not statistically significant ($P > .05$). The Wilcoxon signed rank sum test showed a significantly lower percentage of sealer penetration at 2 mm level than at 5 mm level ($P < .05$).

IV. Discussion

Contemporary methods for smear layer removal include using chemical solution, sonic, ultrasonic devices and laser irradiation. Among them, laser can be used to vaporize pulp tissues, remove the smear layer and eliminate residual tissue in the apical part of root canals (28). Early attempts using laser were focused on smear layer removal or sealing by melting or modifying the dentin surface (29-31). The Nd:YAG laser irradiation was reported to cause morphological changes in dentin by melting and solidifying the root canal dentin layer (32). On the other hand, erbium: yttrium-aluminum-garnet (Er:YAG) laser was reported to be more effective in smear layer removal than Nd:YAG laser without melting or recrystallization of dentin (28, 31, 33). These effects are likely to be based on the photo-thermal effects of laser since the laser devices were used depending on the laser-tissue/target interaction without air and/or water cooling (14).

However, a potential risk of thermal injury to periradicular tissue by overheating has been a major concern of this direct irradiation method because higher level of energy or intensity of laser was required for smear layer removal or disinfection (14). Another concern is that emission of laser beam is unidirectional, which makes it difficult the entire root canal wall to be expose with laser (15). Even though the laser was used with constant spiral motion to maximize the exposed area, studies (15, 34) showed that it was not efficient enough to irradiate completely the whole surface.

Meanwhile, LAI in which laser is irradiated in the root canal full of irrigant solution has been recently introduced for the purpose of smear layer removal (13-18). The mechanism of LAI is based on cavitation. Because of the high absorption of water by the mid-infrared wavelength of lasers (21, 22), the cavitation process generates vapor-containing bubbles, which explode and implode in a liquid environment (35). This subsequently initiates pressure waves/shock waves by inducing the shear force on dentinal wall. In a water-filled root canal, the shock waves could potentially detach the smear layer and disrupt bacterial biofilms (35, 36). To efficiently activate irrigant and generate shock waves in the root canal, lasers with wavelength from 940 to 2940 nm have been used (13-20, 36). The present study was undertaken to examine the LAI effect on the smear layer removal by 1320 nm Nd:YAG laser. Although 1320 nm Nd:YAG laser shows lower absorption coefficient in water than erbium lasers (21, 22), 200 μm flexible fiber of 1320 nm Nd:YAG laser can be applied in the closer proximity of the root apex and thus potentially enables to exert cleansing effect in the area. In addition, since 1064 nm Nd;YAG laser was demonstrated to induce pressure waves or shock waves (20), it was of a clinical interest with regards smear layer removal whether 1320 nm Nd:YAG laser which has higher absorption level (21, 22) than 1064 nm Nd:YAG laser, would induce similar effect or not.

Degree of smear layer removal has been evaluated by observing the debris left in the dentin section using a scanning electron microscope (SEM) in a number of studies (6, 7, 37, 38). SEM analysis provides a detailed view of dentin surface and dentinal tubules at high magnification but not at low magnification (39). Furthermore, it could potentially cause formation of artifacts during the sample preparation (39).

In this study, we did not directly observe the effect of LAI on the removal of smear layer. Rather, the CLSM analysis of sealer penetration into the dentinal tubule was used because it can be a good indicator for evaluating the degree of smear layer removal in *in vitro* tooth model. Moreover, CLSM analysis does not require special sample preparation so there is low risk of producing artifacts (40). Theoretically, the more broadly the sealer penetrates along the circumference of the root canal wall, the better the seal is anticipated to be achieved three-dimensionally, because the interface between the sealer and dentin is increased by sealer penetration, which might improve the sealing ability as well (9, 41, 42). Moreover, the mechanical interlocking of the sealer plug in the dentinal tubules has been suggested to improve retention of the root canal filling material (43, 44). The sealer penetration is also considered beneficial for preventing reinfection of the root canal system, since the sealer can entomb bacteria within the tubules, and if antibacterial sealer is used, the penetrated sealer can kill bacteria located inside the tubules (45, 46).

To remove both organic and inorganic debris of the smear layer, the alternate use of NaOCl and EDTA had been recommended (47). However, alternating NaOCl with EDTA decreases the antibacterial and tissue-dissolving activity of NaOCl per se (48). Furthermore, prolonged use of EDTA can cause dentinal erosion of the root canal by decalcifying the peritubular dentin (49). This could be accelerated with following use of NaOCl by dissolving the already exposed organic matrix (7). Therefore, instead of alternating regimen, the sole effect of LAI on the smear layer removal in the presence of either NaOCl or EDTA was a matter of interest in this study. The result showed that the amount of sealer penetration was significantly higher in laser-activated groups (group NL and EL) and EDTA final flush group (group E) compared with that of NaOCl irrigation group (group N). This implies that LAI with 1320 nm Nd:YAG laser might have some beneficial effects over NaOCl syringe irrigation.

When NaOCl was filled as a final irrigant solution, LAI seems to be as efficient as syringe irrigation of EDTA. Moreover, LAI with NaOCl showed a significantly higher amount of sealer penetration than the 1-minute irrigation of NaOCl alone in both levels of curved canals. The possible explanation for the higher penetration percentage of LAI with NaOCl is oxygen-releasing potential of NaOCl solution. In this regard, Hmud et al (36) demonstrated that aqueous irrigants with oxygen-releasing potential would enhance cavitation formation through the generation of water vapor as well as oxygen.

The samples of LAI with EDTA also showed a greater amount of sealer penetration than those of NaOCl final flush in both levels of the root canal. In the study of George et al (16), lasing of root canal with erbium laser was found to improve the action of ethylenediaminetetraactic acid cetavlon (EDTAC) in smear layer removal. Suggested speculation was that hydraulic stresses created in the EDTAC solution by LAI might agitate the irrigant, thus increase its ambient temperature and increase its penetration into the smear layer and tubules that are already open (16). In this study, application of 1320 nm Nd:YAG laser in EDTA filled canal showed broader sealer penetration around the root canal wall although the difference was not statistically significant. Potential influencing factor for the result is that laser might have limited effect in the small and curved root canal since energy level used in the current study may not have been strong enough to activate EDTA solution. Therefore future study is required to evaluate laser effect in EDTA solution at the different energy levels.

In terms of level of section, significantly less sealer penetration was observed in the samples of 2 mm level than those of 5 mm level.

These regional differences were reported in other studies (9, 39, 50). The efficacy of smear layer removal method is reduced closer to the root apex (37, 39). Fewer dentinal tubules and smaller diameters of dentinal tubules in apical area could also be responsible for this result (51).

In the majority of the samples, greater sealer penetration toward the outer part of the root curvature than toward the inner part was observed, although these were not analyzed statistically. This observation is similar to other studies (9, 50). One possible reason for this is that the cutting of the root canal dentin by mechanical instrumentation is greater at the outer part of the root curvature than at the inner part. Therefore, the smear layer removal by either syringe irrigation or LAI can be facilitated in the already exposed dentinal tubular surface area.

When the laser is used for intracanal application, thermal damage to surrounding periodontal tissue is of major concern. Since apical portion of the root is thin and the fiber will pass closer to the canal wall, this area will be more susceptible to thermal injury (52). The threshold level for bone survival was reported 47℃ for 1 minute, which is an increase of 10℃ above the core body temperature (53). It was demonstrated that temperature rise using diode laser (810 nm, 4 W, 10 ms pulse length/ 10 ms interval duration) under even circling movements for 5, 8, or 10 seconds was below 6℃ (54). When irradiation was used without movement, temperature was raised up to 18℃. If the energy level or duration of laser application was not adequate, thermal damage and morphological changes became visible (55). To resolve this issue, Camargo et al (56) suggested using laser with a circular movement inside root canal to minimize overheating of the root canal dentin. Therefore, relatively low power setting (150 mJ/pulse and 10 Hz; average power 1.5 W) and 10 seconds of resting time between laser irradiation were used in the current study.

Another concern regarding LAI is a possibility of irrigant extrusion from the apex (57). The rapid formation of vapor bubbles may cause damage to the apical constriction and extrusion of irrigating solution beyond the root apex. In this respect, Matsuoka et al (58) suggested that 200 or 320 μm fibers of 2740 nm Er,Cr:YSGG laser (20 Hz, 2 W) should be kept 2 and 3 mm away from the anatomical apex to prevent destruction of the apical constriction. Therefore, in the present study, laser fiber tip was applied 3 mm away from the apex with lower power setting (1.5 W). The risk of extrusion is expected to be lower for 1320 nm Nd:YAG laser because it is less absorbed by water compared with higher wavelength erbium lasers.

A flow visualization study (18) revealed that the secondary cavitation bubbles are formed during the collapse and renucleation of a large bubble. The cleaning efficacy of LAI is speculated to be further enhanced by secondary cavitation bubbles, since they are excited by the bubble collapse of the consecutive laser pulse (18). Therefore, further research is required to examine the efficacy of LAI in terms of cleaning the entire root canal including hard-to-reach areas such as isthmus and ramifications. Further investigation of comparing LAI effect with other irrigation methods such as sonic, passive ultrasonic irrigation, and pressure alternation devices is also required.

V. Conclusions

Within the confines of this study,

1. In 5.25% NaOCl solution filled canal, 1320 nm Nd:YAG LAI increased sealer penetration around the canal wall in both 2 and 5 mm levels ($P < .05$).
2. In 17% EDTA solution filled canal, 1320 nm Nd:YAG LAI also showed higher sealer penetration than syringe irrigation in both levels, but the difference was not significant ($P > .05$).
3. Therefore, prior to root canal obturation, 1320 nm Nd:YAG LAI, especially with 5.25% NaOCl solution might be beneficial in enhancing sealer penetration in curved canals. Further research is required to investigate the effective laser parameters for each irrigating solution.

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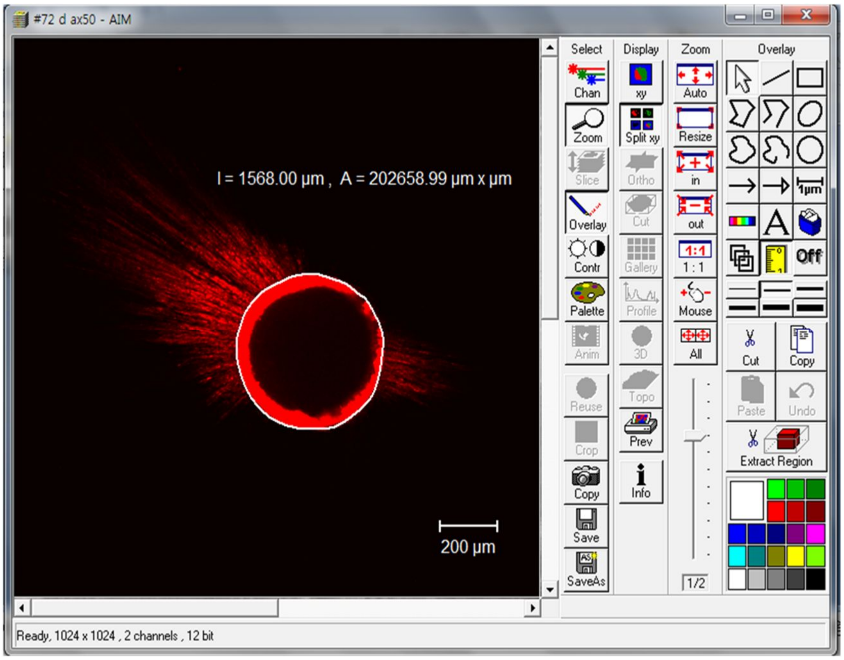
Table 1. Mean percentage of the canal walls in which sealer penetrated dentinal tubules

Level of section	Group	Mean ± SD (%)
2 mm from apex	N (NaOCl only)	16.0 ± 14.9 [a]
	E (EDTA only)	22.3 ± 18.4 [b]
	NL (NaOCl with laser)	35.3 ± 23.5 [b]
	EL (EDTA with laser)	40.0 ± 28.7 [b]
5 mm from apex	N (NaOCl only)	34.9 ± 26.7 [A]
	E (EDTA only)	57.2 ± 19.0 [B]
	NL (NaOCl with laser)	68.5 ± 21.6 [B]
	EL (EDTA with laser)	76.6 ± 28.8 [B]

Different superscript letters within each level indicate statistically significant differences ($P < .05$).

Figure 1. For measuring root canal curvature, a radiograph of each tooth in which a #15 K−file was inserted into the canal was used. First, a straight line along the long axis of the canal was drawn. Then the second line was drawn from a point where the instrument started to deviate from the first line to the point of root apex. The acute angle formed by two lines was measured as the root canal curvature.

(A)


#72 d ax50 - AIM
l = 1568.00 µm , A = 202658.99 µm x µm
200 µm
Ready, 1024 x 1024 , 2 channels , 12 bit

(B)

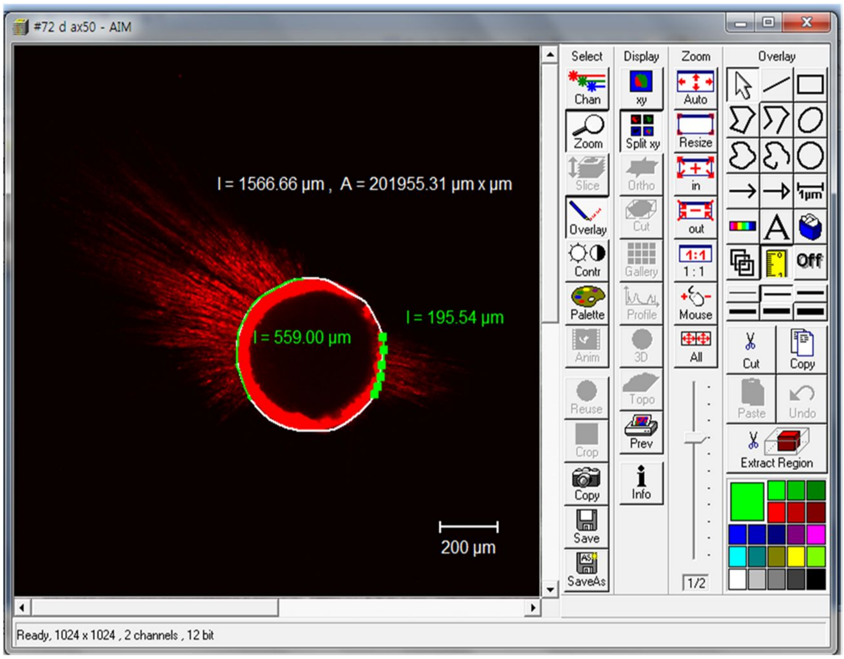

#72 d ax50 - AIM
l = 1566.66 µm , A = 201955.31 µm x µm
l = 559.00 µm
l = 195.54 µm
200 µm
Ready, 1024 x 1024 , 2 channels , 12 bit

Figure 2. Percentage of sealer penetration was measured using the measuring tool of the software (LSM Image Examiner, Carl Zeiss). (A) Circumference of the root canal wall (white line) was measured. (B) Areas along the white line into which the sealer penetrated the tubules with any distance were outlined with green line and measured. Then the percentage of sealer penetration was calculated by dividing the length of green line by the length of white line.

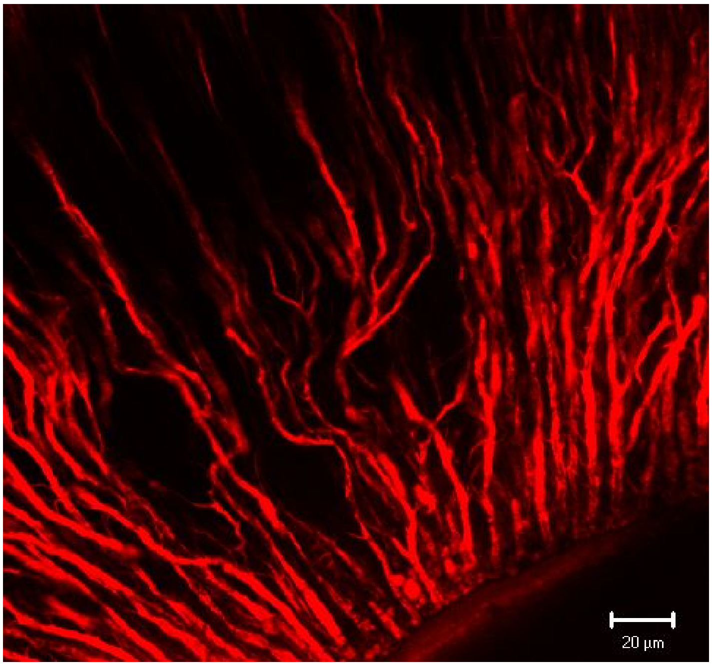


Figure 3. CLSM image of sealer−dentin interface showing fluorescent dye−labeled sealer penetrating into dentinal tubules (400X).

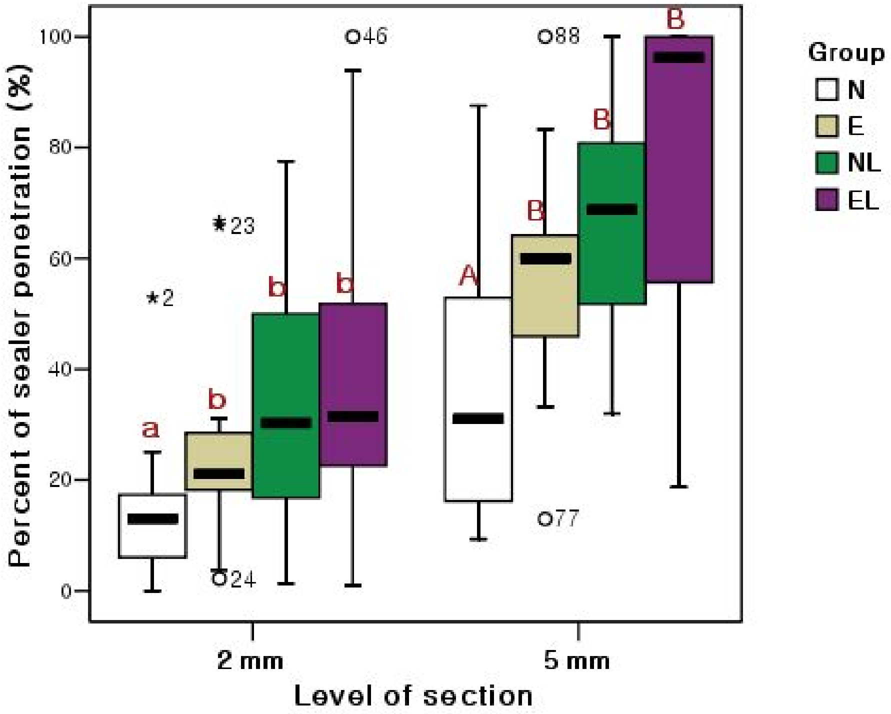


Figure 4. Percentage of the canal walls in which sealer penetrated dentinal tubules. Different letters within each level indicate significant differences (P < .05).

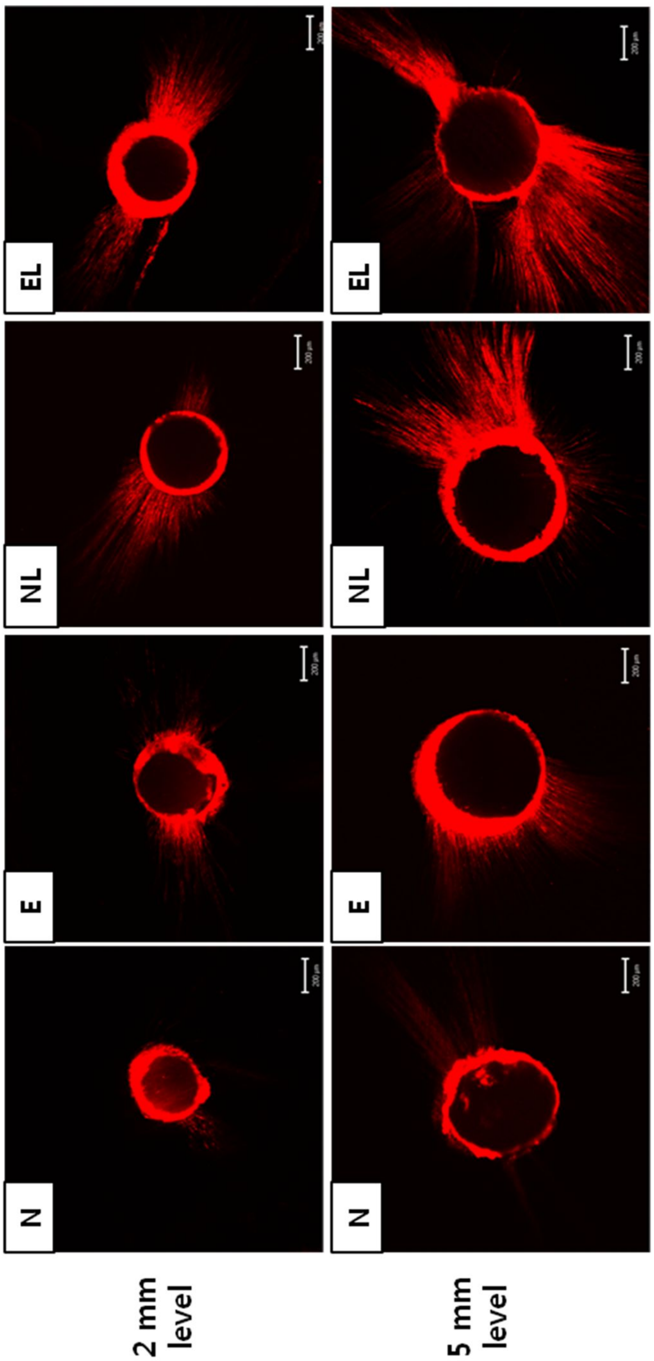

N
E
NL
EL
2 mm level
5 mm level

Figure 5. Representative CLSM images from each group (original magnification, 50X). N, E, NL and EL indicate group N, E, NL and EL respectively. Images on upper row represent samples from 2 mm level and lower row from 5 mm level.

-국문초록-

만곡 근관에서 1320nm Nd:YAG 레이저를 이용한 근관 세척 방법에 따른 근관 봉합재의 침투도에 관한 연구

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서론

최근 근관 세척 시 중적외선 파장의 Erbium 레이저를 이용하여 도말층 제거 향상 효과가 있었음이 보고된 바 있지만 Nd:YAG 레이저, 특히 1320nm 파장의 Nd:YAG 레이저의 효과에 대한 연구는 부족하다. 본 연구는 만곡 근관에서 5.25% NaOCl 용액이나 17% EDTA 용액이 채워진 근관에 1320nm Nd:YAG 레이저 적용 시의 도말층 제거 효과를 근관 봉합재의 상아세관 내 침투도를 측정하여 관찰, 비교하기 위해 시행되었다.

재료와 방법

발거된 대구치 중 상악 대구치의 근심, 원심 협측 근관과 하악 대구치의 근심 근관의 만곡이 20-40°인 63개 치아를 대상으로 하였다. 각 치아의 근관을 NaOCl 용액으로 세척하면서 ProFile로 #30/.06까지 형성한 후 네 개의 실험군(n=15)으로 나누었다: N군; 5.25% NaOCl 용액을 채운 상태에서 laser를 조사하지 않고 laser fiber만 적용, E군; 17% EDTA 용액을 채운 상태에서 laser를 조사하지 않고 laser fiber만 적용, NL군; N군과 동일하게 처리하되 laser를 조사, EL군; E군과 동일하게 처리하되 laser를 조사. 모든 실험군에서 laser fiber를 근관내 5초씩 4번 적용시켰고, 적용 사이에는 NaOCl(N, NL군) 용액이나 EDTA(E, EL군) 용액(3ml)으로 10초간 세척하였다. 근관 형성 시 근관 세척제를 전혀 사용하지 않은 치아를 음성 대조군(n=3)으로 사용하였다. 최종 세척 후 형광염료를 혼합한 근관 봉함재(AH Plus)와 gutta-percha를 이용하여 continuous wave 가압법으로 충전하였다. 근첨에서 2, 5mm 되는 부위를 500μm 두께로 자른 후 공초점 레이저 주사현미경으로 관찰하여 근관 둘레에서 근관 봉함재가 상아세관으로 침투한 부위의 비율을 측정하여 비교하였다.

결과

E, NL, EL군에서 근관 봉함재 침투율이 N군에서 보다 유의하게 높았다($P < .05$). 근관 내에 NaOCl 용액을 채운 경우, 레이저를 적용했을 때(NL군), 레이저를 적용하지 않은 경우(N군) 보다 근첨 2, 5mm 부위 모두에서 근관 봉함재가 더 넓게 침투하였다($P < .05$). 근관 내에 EDTA

용액을 채웠을 때, 레이저를 적용한 경우(EL군) 근관 봉함재가 더 넓게 침투했으나 레이저를 적용하지 않은 것(E군)과 통계적인 차이는 없었다(P> .05).

결론

만곡 근관에서 1320nm Nd:YAG 레이저로 5.25% NaOCl이나 17% EDTA 용액을 활성화 시킨 경우 NaOCl 용액으로만 근관 세척한 경우보다 근관 봉함재의 침투율이 높았다. NaOCl 용액을 사용할 때 레이저 적용으로 근관 봉함재 침투가 유의하게 증가하였고, EDTA 용액을 사용했을 때는 레이저 적용으로 봉함재 침투가 증가하였으나 통계적으로 유의한 차이는 없었다. 따라서 만곡 근관에서 NaOCl 용액을 근관 세척제로 사용할 경우 1320nm Nd:YAG 레이저가 근관 봉함재의 침투를 증가시키기 위해 사용될 수 있을 것으로 기대된다.

주요어: 레이저 근관 세척, EDTA, NaOCl, 공초점 레이저, Nd:YAG, 봉함재 침투

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