Occluding Effect of the Application of Fluoride Compounds and Desensitizers on Dentinal Tubules

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This study compared and analyzed the occluding effects of fluoride compounds and desensitizers, which are commonly used in dental clinics, on dentinal tubules. This study also evaluated the persistence of the active ingredients over time by performing toothbrushing with an electric toothbrush. Thirty-five molar teeth, which had been extracted within the past 3 months from healthy people without tooth decays, amalgam fillings, or dental crowns, were divided into 4 pieces each. Of these, 135 teeth pieces were used as study specimens. These specimens were divided into a control group, an untreated group, and 5 experimental groups (acidulated fluoride gel, fluoride varnish, Gluma, Super Seal, and SE-Bond). The specimens were then subjected to toothbrushing equivalent to 1 week (140 times), 2 weeks (280 times), and 4 weeks (560 times), and the occluding effects on dentinal tubules in 3 regions of each specimen were examined under a scanning electron microscope. The fluoride varnish treated group showed the highest degree of dentinal tubule occlusion effects during the first, second, and fourth weeks of toothbrushing, with the SE-Bond treated group showing the second highest degree and the Gluma treated group showing the lowest degree. After 4 weeks of toothbrushing, the Gluma treated group and the Super Seal treated group showed the lowest degrees of dentinal tubule occlusion effects. In summary, the fluoride varnish treated group and the SE-Bond treated group displayed higher occlusion effects even after 4 weeks of treatment than did the other experimental groups. Therefore, it is the authors’ belief that fluoride varnish and SE-Bond are effective for treating dentinal hyperesthesia.

Key Words: Dentin sensitivity, Dentinal tubules, Dentin desensitizing agents, Fluorides, Scanning electron microscope

Introduction

The importance of health care has increased based on the developments in science and technology, and improvements in the quality of life\(^1\). With increasing life expectancy, the incidence of periodontal diseases, gingival recession, dental caries, and dentin sensitivity, due to improper brushing of teeth, and cervical abrasion have also increased\(^2\).

Dentin sensitivity is defined as a short and sharp pain that develops due to exposure to abrupt temperature changes, and mechanical, chemical, tactile, or osmotic stimulations\(^3,4\). This chronic\(^3\) symptom was observed in 4% to 74% of all adults\(^6,7\).
The theories explaining such hypersensitivity include the transducer theory, modulation theory, gate control theory, and hydrodynamic theory. Among these, the hydrodynamic theory has been most widely accepted. According to this theory, the amount of dentinal fluid decreases due to stimulation on the exposed dentin surface, and the dentinal tubule contents quickly moved onto the exposed dentin surface, causing pain. According to Pashley, the influx in odontoblast, which was caused by the movement of dentinal fluid due to external stimulation, and the rapid movement of the dentinal fluid transformed the nerve fiber terminal, thereby causing pain. The size and number of the dentinal tubules are associated with the level of dentinal tubule permeation. The increased size and diameter of the dentinal tubule are the most important factors that worsen hypersensitivity.

The suggested methods of treating dentin sensitivity include the following based on the abovementioned theories: inducing tertiary dentin formation by applying stimulation, inhibiting dentinal fluid movements by physically occluding the dentinal tubule surface, and occluding dentinal tubules through a smear layer formation or the use of hypersensitivity agents. Desensitizing agents are widely used in dental hospitals and clinics to occlude dentinal tubules. They must not cause stimulation or pain when coated on the pulp; application time must be brief; they must be free from pigmentation; and their effects must last a long time consistently.

Fluoride compounds were suggested as desensitizing agents by Lukomsky for the first time in 1941. Hoytt and Bibby reported that sodium fluoride was effective against dentinal tubule occlusion. Walters confirmed that dentifrices, including SnF2, had been effective in treating dentinal tubule occlusion. Potassium oxalate has also been reported as effective against dentinal tubule occlusion when the smear layer on the surface of the tooth is removed, calcium oxalate crystals are formed, and dentinal tubules become occluded. This means that the mechanism of the hypersensitivity agent is focused on occluding, open dentinal tubules.

Agents with various ingredients have been used for treating dentine hypersensitivity. The occlusion of dentinal tubules is important in relieving symptoms, but its long-lasting effects are more significant. Hong et al. reported that daily brushing of teeth could inhibit the effects of desensitizing agents. Lee et al. reported that brushing of teeth one or two weeks after the coating of desensitizing agents resulted in an increase in dentin permeability, thus decreasing their effects. The occlusion effects of desensitizing agents have been evaluated in previous studies, but the abrasion of the desensitizing agent over the course of time had not been sufficiently reported.

In this study, the occluding effects of fluoride compounds, such as acidulated phosphate fluoride (APF) and fluoride varnish, and desensitizing agents, such as Gluma, Super Seal, and SE-Bond, which are widely used in dental hospitals and clinics, on dentinal tubules were compared and analyzed by using a scanning electron microscope (SEM). Furthermore, the effects of electronic tooth-bru-

| Desensitizer       | Composition                                      | Manufacturer                      |
|--------------------|--------------------------------------------------|-----------------------------------|
| APF                | 1.23% APF                                        | Germiphene, Brantford, ON, Canada  |
| Fluoride varnish   | 5% sodium fluoride, Hydroxyethylmethacrylate, Glutaraldehyde, Purified water, Mequinol | 3M, Maplewood, MN, USA            |
| Gluma              | Hydroxyethylmethacrylate, Glutaraldehyde, Purified water, Mequinol | Heraeus Kulzer, Hanau, Germany    |
| Super Seal         | Oxalic acid, Potassium salt                      | Phoenix Dental, Fenton, MO, USA   |
| SE-Bond            | N-tolyglycine-glycidyl methacrylate, Biphenyl dimethacrylate, Acetone | Bisco, Schaumburg, IL, USA        |

APF: acidulated phosphate fluoride.
shing machines on the materials were evaluated over the course of time.

**Materials and Methods**

1. Materials

   The fluoride compounds used in this study included APF (Germiphene, Brantford, ON, Canada) and fluoride varnish (3M, Maplewood, MN, USA), and the desensitizing agents were Gluma (Heraeus Kulzer, Hanau, Germany), Super Seal (Phoenix Dental, Fenton, MO, USA), and SE-Bond (Bisco, Schaumburg, IL, USA) (Table 1).

2. Tooth sample preparation

   Approval from the institutional review board of Eulji University was obtained prior to this study (IRB No. EU15-27). Thirty-five healthy human molars without caries, restorations, and prostheses, which were extracted within the last three months, were used. Soft tissues and residuals attached to the dental root were removed by using an ultrasonic scaler (EMS Scaler; EMS, Nyon, Switzerland) then cleansed. The cemento-enamel junction area of the cleansed tooth was transected by using a diamond wheel disk (Komet; Düsseldorf, Nordrhein-Westfalen, Germany). For this study, the dental root was chosen between the crown and dental root that were produced by the transection. After removing the dental root’s bottom half, the remaining dental root was cut vertically and horizontally, and divided into four sections by using a disk bur (Komet). Finally, 2 x 2 mm samples were prepared. A total of 135 samples were selected. Acrylic resin (Dentsply international Inc., York, PA, USA) was placed into the Teflon mold, before burying the sample with the cement facing upward. After the resin was set, the surface of the dentin was polished by using a LaboPol-5 grinder polisher (Struers, Copenhagen, Denmark) at 600, 1,200, and 4,000 grits. The prepared dentin sample was deposited in 6% citric acid (Daejung, Cheongju, Korea) for 90 seconds to penetrate the dentinal tubules. After the sample was exposed to acid, its surface was sufficiently cleansed with distilled water, and then dried at room temperature.

3. Treatments for each group

   Of the prepared 135 samples, 60 were assigned equally (at 10 samples per group) to six groups (control group and the experimental groups, namely, the APF group, the fluoride varnish treated group, the Gluma treated group, the Super Seal treated group, and the SE-Bond treated group).

   Any additional treatments were not conducted in control group. In the APF, the samples were dried after applying 1.23% APF gel. The samples of the fluoride varnish treated group were also left to dry after applying fluoride varnish via an applicator. In the Gluma treated group, Gluma was applied for 30 ~ 60 seconds after the dental prophylaxis was done. The moisture was removed from the samples, and then compressed air was sprayed to the surface of the samples until the thin fluid film and the gloss of the surface disappeared. Soon after, they were thoroughly cleansed with water. In the Super Seal treated group, the dental prophylaxis was done for the samples. The samples were left to dry for 30 seconds after the application of the Super Seal, and then they were left to dry again for one minute. In the SE-Bond treated group, the samples were left to dry for 20 seconds after conducting dental prophylaxis and applying a primer. Soon after, SE-Bond was applied to the sample. It was left to dry again, and then received light irradiation.

4. Electronic tooth-brushing machines

   Other than the control group, 15 samples were assigned to each experimental group. To reproduce the phenomena developing on the samples through brushing after coating the desensitizing agent, a slim, three-line regular toothbrush (WD237; WEDENT Chiarang, Gimpo, Korea) was put on the base of the electric toothbrush, and horizontal back and forth brushing was conducted for one week (140 times), 2 weeks (280 times), and 4 weeks (560 times), using five samples per week.

   Toothbrushing frequency was determined as 140 times a week (two times per a day and 10 back and forth movements per one time toothbrushing). Toothbrushing frequency was determined to be 140 times a week with 10 back and forth movements per one-time toothbrushing, twice a day. As to the number of toothbrushing per day,
the twice-a-day frequency is similar to the study by Oh\textsuperscript{25}) and the study by Choi and Han\textsuperscript{26}), who conducted the toothbrushing two to three times a day and twice a day, respectively. As to the brush stroke frequency, it is similar to the study by Hong et al.\textsuperscript{23}), who conducted toothbrushing 140 times a week, and the study by Mandikos et al.\textsuperscript{27}), who conducted 44 times of one-way brushing a day.

5. Observation and analysis through SEM

All the samples dried at room temperature were fixed by using a carbon tape, coated with 150 nm thickness ion sputter (E-1030; Hitachi, Tokyo, Japan), and the randomly-selected three areas on the surface were observed using SEM (S-4700; Hitachi) at 10 kV and 3,000 times magnification.

1) Analysis items

The mean occlusion levels in the unit surface of the control group and the experimental groups were compared.

2) SEM analysis criteria

The mean value was calculated after adding all the dentinal tubule surfaces observed in the SEM images. Based on the mean value, the occlusion levels of each dentinal tubule were evaluated according to the scoring table (Table 2).

Identical images were given to three estimators who calculated the score by using the same method, and then the scores were averaged to obtain the final occlusion level score\textsuperscript{14}).

6. Data analysis

One-way analyses of variance were used to compare the occlusion effects on dentinal tubules at 1, 2, and 4 weeks after the treatment. For multiple comparisons, Scheffé post hoc tests were conducted.

Repeated measure ANOVA was used to evaluate the efficiency of the active ingredient at 1, 2, and 4 weeks after the treatment. For multiple comparisons, Scheffé post hoc tests were conducted. PASW Statistics ver. 18.0 (IBM Co., Armonk, NY, USA) was used for statistical processing. Statistical significance was accepted at $p < 0.05$.

### Results

1. SEM observation on the dentinal tubule surface

1) Before and after the treatment

The specimen surface in control group was clean and smooth, and open dentinal tubules were clearly observed (Fig. 1A). In the experimental groups, all the dentinal tubules of the APF group were occluded with fluoride deposits, and the surface was covered with irregular granular (Fig. 1B). In the fluoride varnish treated group, all the dentinal tubules were occluded by the fluoride deposits, but the surface was smooth, and crystals were observed in some areas (Fig. 1C). In the Gluma treated group, all the dentinal tubules were occluded with deposits, but they were thin enough to reveal the outline of dentinal tubules. The surface was slightly rough, and crystals were observed (Fig. 1D). In the Super Seal treated group, dentinal tubules were occluded with fine particles, and irregular surfaces were observed (Fig. 1E). In the SE-Bond treated group, dentinal tubules were occluded with deposits, and slightly rough surfaces were observed (Fig. 1F).

2) One week after electronic tooth-brushing machines

In the APF group, some of the occluded dentinal tubules were opened after the treatment, and rough surfaces were observed (Fig. 2A). In the fluoride varnish treated group, most of the dentinal tubules were occluded due to fluoride deposit crystals (Fig. 2B). In the Gluma treated group, many dentinal tubules were open, but some of them were occluded with crystals (Fig. 2C). In the Super Seal treated group, dentinal tubules were occluded with fine particles, and irregular surfaces were observed (Fig. 2D). In the

| Table 2. Occlusion Effects Score |
|----------------------------------|
| Score | Occlusion of dental tubule wide |
|-------|---------------------------------|
| 0     | In case there are no occlusion  |
| 1     | In case there are less occlusion than 1/4 |
| 2     | In case there are 1/4 ~ 1/2 occlusion |
| 3     | In case there are 1/2 ~ 3/4 occlusion |
| 4     | In case there are more occlusion than 3/4 |
| 5     | In case there are fully occlusioned |
Fig. 1. Scanning electron microscope images after applying desensitizers (×3,000). (A) Control, (B) acidulated phosphate fluoride, (C) fluoride varnish, (D) Gluma, (E) Super Seal, and (F) SE-Bond.

SE-Bond treated group, the rough surface became smooth, and some of the dentinal tubules were open (Fig. 2E). In the Gluma treated, Super Seal treated, and APF groups, more dentinal tubules were open compared to the fluoride varnish treated and SE-Bond treated groups (Fig. 2B ~ E).
3) Two weeks after electronic tooth-brushing machines

In the APF group, more dentinal tubules were open compared to the first week. The shape of the dentinal tubules was irregular, and some of them were occluded with fluoride deposits (Fig. 3A). In the fluoride varnish treated group, more dentinal tubules were open compared to the first week, but few of them were completely open (Fig. 3B). In the Gluma treated group, most of the dentinal tubules were open, and their size increased. Only a small number of samples were occluded with deposits (Fig. 3C).
In the Super Seal treated group, the surface of the open dentinal tubules was not large, but most of the dentinal tubules were open (Fig. 3D). In the SE-Bond treated group, a number of open dentinal tubules in various sizes were observed (Fig. 3E). In the Gluma treated group, more open dentinal tubules and larger surfaces were observed, compared to other experimental groups (Fig. 3A ~ E).

4) Four weeks after electronic tooth-brushing machines
In the APF group, most dentinal tubules were open, and
some of the dentinal tubules were expanded (Fig. 4A). In the fluoride varnish treated group, fluoride deposits were removed to reveal a smooth surface. Most dentinal tubules were occluded (Fig. 4B). In the Gluma treated group, most dentinal tubules were open (Fig. 4C). In the Super Seal treated group, most dentinal tubules were open, and deposits were removed to reveal a smooth but uneven surface (Fig. 4D). In the SE-Bond treated group, open dentinal tubules were observed, but most of them were partly open, and the surface was irregular (Fig. 4E). In the

![Image of Scanning Electron Microscope Images](image_url)

**Fig. 4.** Scanning electron microscope images 4 weeks later after toothbrushing \((\times 3,000)\). (A) Acidulated phosphate fluoride, (B) fluoride varnish, (C) Gluma, (D) Super Seal, and (E) SE-Bond.
fluoride varnish treated and the SE-Bond treated groups, less and smaller open dentinal tubules compared to the APF, Gluma treated, and Super Seal treated groups were observed (Fig. 4A ~ E).

2. Efficiency evaluation of active ingredients using SEM

1) One week after electronic tooth-brushing machines

The fluoride varnish treated and SE-Bond treated groups showed the highest level of dentinal tubule occlusion one week after the electronic tooth-brushing machines, followed by the APF group and the Super Seal treated group, showing statistically insignificant differences (p > 0.05), but the difference from the fluoride varnish treated group was significant (p < 0.05). The occlusion level of the Gluma treated group was the lowest, showing a significant difference from the fluoride varnish treated group and the SE-Bond treated group (p < 0.05; Table 3).

2) Two weeks after electronic tooth-brushing machines

Two weeks after the electronic tooth-brushing machines, the highest dentinal tubule occlusion level was observed in the fluoride varnish treated group, followed by the SE-Bond treated group and the Super Seal treated group, showing a significant difference (p > 0.05), and by the APF group, showing a significant difference from the fluoride varnish treated group (p < 0.05). The Gluma treated group showed the lowest occlusion level, showing a significant difference from all the experimental groups (p < 0.05; Table 3).

3) Four weeks after electronic tooth-brushing machines

Four weeks after the electronic tooth-brushing machines, the highest occlusion level was observed in the fluoride varnish treated group and the SE-Bond treated group, followed by the APF group, showing a significant difference from the fluoride varnish treated group and the SE-Bond treated group (p < 0.05). The Super Seal treated group and the Gluma treated group showed lower occlusion levels than other experimental groups, and showed a significant difference from the fluoride varnish treated group, the SE-Bond treated group, and the APF group (p < 0.05; Table 3).

Discussion

Dentine hypersensitivity is a common symptom, and it can be defined as a specific, perceptual response or pain reaction against stimulation applied to the exposed dental root surface.

Dentinal tubules are exposed mainly because of dental root exposure and the loss of the dental root surface cementum. Various symptoms and patterns of hypersensitivity appear consequently.

The methods of relieving dentin sensitivity include inhibition of the liquid within dentinal tubule by physically occluding the dentinal tubule surface; application of stimulation to promote tertiary dentin formation; smear layer formation to occlude dentinal tubules; and induction of occlusion with the use of drugs.

In this study, fluoride compounds and desensitizing agents were applied to dentinal tubules to observe dentinal tubule occlusion. As a result, in the experimental groups, such as the APF group and the fluoride varnish treated group, fluoride deposits were observed to have occluded

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**Table 3. The Effect of Dentinal Tubule Occlusion over Time**

| Group                | n  | 1 wk         | 2 wk         | 4 wk         | p-value     |
|----------------------|----|--------------|--------------|--------------|-------------|
| Fluoride varnish     | 15 | 4.29±0.091<sup>a</sup> | 3.61±0.097<sup>a</sup> | 3.47±0.102<sup>a</sup> | <0.0001     |
| Acidulated phosphate fluoride | 15 | 3.63±0.115<sup>bc</sup> | 2.94±0.106<sup>b</sup> | 2.33±0.091<sup>b</sup> | <0.0001     |
| Gluma                | 15 | 3.29±0.129<sup>c</sup> | 2.33±0.126<sup>c</sup> | 1.37±0.068<sup>c</sup> | <0.0001     |
| Super Seal           | 15 | 3.52±0.101<sup>bc</sup> | 3.15±0.103<sup>abc</sup> | 1.78±0.085<sup>c</sup> | <0.0001     |
| SE-Bond              | 15 | 3.92±0.082<sup>ab</sup> | 3.42±0.115<sup>ab</sup> | 3.10±0.093<sup>a</sup> | <0.0001     |

Values are presented as number only or mean±standard deviation.

<sup>a</sup> In the same column, different superscript letters denote significant differences between groups by Scheffé post hoc (α=0.05). p-values were determined by one-way ANOVA (α=0.05).
dentinal tubules. These outcomes corresponded to the results of a previous study that confirmed a relieved hypersensitivity due to the fluorides that occluded dentinal tubules \(^{28}\). In the study of Dondi and Malferrari \(^{30}\) that applied Gluma to the hypersensitive dentin, glutaraldehyde and hydroxyethylmethacrylate (HEMA) included in Gluma formed deposits when they reacted with dentinal fluid protein, thereby resulting in occluded dentinal tubules. The Gluma treated group of this study showed the same result; glutaraldehyde and HEMA ingredients, occluded dentinal tubules. But the deposit layer was so thin that the shape of the dentinal tubules was observed. Kolker et al. \(^{16}\) reported similar results to this study; the Gluma treated group showed a thin layer on dentinal tubules. In the Super Seal treated group, all the dentinal tubules were occluded with deposits, and irregular surfaces were observed. Arrais et al. \(^{31}\) reported that the oxalate crystals of Super Seal occluded dentinal tubules. In the SE-Bond treated group, dentinal tubules were occluded with deposits, and slightly rough surfaces were observed. In the study of Jang et al. \(^{32}\), bonding agent covered dentinal tubules to form a film that occluded dentinal tubules. The differences in occlusion patterns and surface roughness might be due to the difference in the size of the active ingredient particles, which determined the thickness and shape of dentinal tubule occlusion.

Meanwhile, Lee et al. \(^{24}\) reported that the dentinal penetration right after applying the desensitizers rapidly fell, but that, one or two-week later after toothbrushing, the dentinal penetration increased. The study by Lee \(^{33}\) on the dental tubule occlusion effect of desensitizing agents reported that the 50-time toothbrushing with desensitizing toothpaste offered a greater dental tubule occlusion effect than the 150-time toothbrushing with other toothpastes.

In addition, Lee et al. \(^{30}\) reported that the dentinal tubule size increased as the exposure time of the dentin to the desensitizing toothpaste increased based on the experiment results regarding the deposited dentin, wherein a toothpaste containing nano-sized carbonate apatite was applied in a decalcification solution. It was found that the efficient time of the active ingredients of desensitizing agents was affected by the frequency of the brush strokes and the exposure time to the acid.

In this study, toothbrushing was conducted over the course of time to evaluate the persistency of the active ingredient. As a result, the fluoride varnish treated group showed the highest degree of dentinal tubule occlusion effects during the first, second, and fourth weeks while toothbrushing, and the SE-Bond treated group showed the second highest degree. The lowest group of the dentinal tubule occlusion effects was the Gluma treated group. After four weeks of toothbrushing, the Gluma treated group and Super Seal treated group showed the lowest degrees of dentinal tubule occlusion effects.

Jang et al. \(^{32}\) also reported that the SE-Bond treated group showed a higher occlusion level than the Gluma treated group. In this study, the fluoride varnish treated group showed a higher dentinal tubule occlusion level than the APF group. This corresponded to that of Lee \(^{14}\) the fluoride varnish treated group showed a higher occlusion level than the APF group. This might be due to the fluoride varnish that slowly permeated into the dentinal tubules. As a result, its effects were lasted for a longer period than in the APF group. In the Gluma treated group, most dentinal tubules were open because the deposits were thin enough to be abraded through toothbrushing.

According to this study, even four weeks after the electronic tooth-brushing machines, the fluoride varnish treated and SE-Bond treated groups showed higher levels of occlusion and active ingredient efficiency than the APF, Gluma treated, and Super Seal treated groups. Therefore, the use of fluoride varnish and SE-Bond may be effective as hypersensitivity treatments.

**Summary**

In this study, the occluding effects of fluoride compounds and desensitizing agents, which are frequently used in dental hospitals and clinics, were compared and analyzed using SEM. Furthermore, electronic tooth-brushing machines was conducted to evaluate the efficiency of the active ingredient over the course of time.

The outcomes are as follows: the fluoride varnish treated group showed the highest degree of dentinal tubule
occlusion effects during the first, second, and fourth weeks while toothbrushing, and the SE-Bond treated group showed the second highest degree. The lowest group of the dentinal tubule occlusion effects was the Gluma treated group. After four weeks of toothbrushing, the Gluma treated group and Super Seal treated group showed the lowest degrees of dentinal tubule occlusion effects.

In summary, both the fluoride treated and the use of desensitizing agents were effective in treating occluding dentinal tubules. Particularly, the use of fluoride varnish and SE-Bond resulted in higher occlusion level than in other experimental groups, even four weeks after treatment. Therefore, fluoride varnish and SE-Bond are considered effective hypersensitivity treatments.

요 약

본 연구는 치과병원에서 일반적으로 사용되고 있는 불소화합물과 지각과민처치제의 상아세관 폐쇄효과를 비교 분석하고, 전동칫솔질을 시행하여 시간경과에 따른 유효성분의 저속력을 평가하고자 하였다. 발거진 지 3개월 이내의 우식이나 수복, 보철물 없는 건전한 사람의 대구치 35개를 선택하여 3등분하였고 이 중 135개의 시편을 본 연구에 사용하였다. 이들 시편을 아무런 처치를 하지 않은 대조군과 5개의 실험군으로 구분하였고, 실험군은 산성불화인산염, 불소바니쉬, Gluma, Super Seal, SE-Bond를 선정하여 대상치아에 도포하였다. 이후 1주(140회), 2주(280회), 4주(560회)에 해당하는 전동칫솔질을 시행하였고, 각 시편별 3부위를 주사전자현미경(SEM)으로 상아세관 폐쇄도를 관찰하였다. 그 결과 전동칫솔질 시행 1주, 2주, 4주에서 모두 불소바니쉬 도포군의 상아세관 폐쇄도가 가장 높았으며, 그 다음으로 SE-Bond 도포군이 높게 나타났다. 또한 Gluma 도포군은 다른 실험군에 비해 가장 낮은 상아세관 폐쇄도를 나타냈으며, 찐솔질 시행 4주에서는 Gluma 도포군과 Super Seal 도포군이 다른 실험군에 비해 낮은 상아세관 폐쇄도를 나타냈다. 본 연구를 종합하면, 치약과무시에 의해 얻어진 상아세관 폐쇄도가 높은 것으로 나타났다. 따라서 임상에서 지각과민 치료 시 불소바니쉬와 SE-Bond의 사용이 효과적일 것으로 생각된다.

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