Effect of artificial saliva on permeability of dentin treated with phosphate containing desensitizer measured by digital flow meter

Masafumi KANEHIRA¹, Hiroshi ISHIHATA², Yasuyuki ARAKI³, Hidekazu TAKAHASHI⁴, Keiichi SASAKI⁵ and Werner J. FINGER⁶

¹ Division of Operative Dentistry, Department of Restorative Dentistry, Tohoku University Graduate School of Dentistry, 4-1 Seiryo-machi, Aoba-ku, Sendai 980-8575, Japan
² Division of Periodontology and Endodontontology, Department of Oral Biology, Tohoku University Graduate School of Dentistry, 4-1 Seiryo-machi, Aoba-ku, Sendai 980-8575, Japan
³ Functional Photochemistry and Chemical Biology, Division of Organic- and Bio-Materials Research, Institute of Multidisciplinary Research for Advanced Materials, Tohoku University, 2-1-1 Katahira, Aoba-ku, Sendai 980-8577, Japan
⁴ Department of Oral Biomaterials Engineering, Graduate School of Medical and Dental Sciences, Tokyo Medical and Dental University, 1-5-45 Yushima, Bunkyo-ku, Tokyo 113-8549, Japan
⁵ Division of Advanced Prosthetic Dentistry, Department of Oral Function and Morphology, Tohoku University Graduate School of Dentistry, 4-1 Seiryo-machi, Aoba-ku, Sendai 980-8575, Japan
⁶ Liaison Center for Innovative Dentistry, Tohoku University Graduate School of Dentistry, 4-1 Seiryo-machi, Aoba-ku, Sendai 980-8575, Japan

Corresponding author, Hiroshi ISHIHATA; E-mail: isi@m.tohoku.ac.jp

The aim of this study was to investigate the effects of artificial saliva on permeability measured using a highly sensitive digital flow meter of dentin discs treated with a phosphate containing desensitizer compound (Teethmate desensitizer; TD). Four random groups (n=10) were treated either with TD or distilled water (DW), then stored in artificial saliva (AS) or DW for 1 day, 1 week and 1 month. Flow rates under 2 kPa pressure were calculated as percentage reduction (PR%) from the baseline. The PR% of TD/AS group was significantly lower after 1 day and 1 week, but the PR% of 1 month groups among TD/AS, TD/DW and DW/AS were not significantly different. The SEM photograph of TD/AS group displayed that the dentin surface was densely covered with mineral deposits. Ca and phosphate ions from the artificial saliva could penetrate into the tubules and precipitate as hydroxyapatite, resulting in the reduction in permeability.

Keywords: Dentin permeability, Dentin sensitivity, Artificial saliva, Flow meter, Hydrodynamics

INTRODUCTION

Cervical dentin hypersensitivity (DH) is a very common pain condition encountered by 3 to 98% of the adult population⁷. In particular patients with periodontal diseases are affected by this oral pain condition²,⁸,⁹. According to the definition of the Canadian Advisory Board dentin hypersensitivity is defined as “short, sharp pain arising from exposed dentin in response to stimuli typically thermal, evaporative, tactile, osmotic or chemical and which cannot be ascribed to any other form of dental defect or disease”⁸. This condition is present only when cementum or enamel covering the dentin is lost and when dentinal tubules are exposed, that are patent at both ends. The globally accepted explanation for the mechanism that triggers pain is Brännström’s hydrodynamic theory⁵,⁶, suggesting that external stimuli, as described above induce rapid inward or outward fluid shifts within the dentinal tubules that cause pain due to stimulation of A-δ nerve fiber endings. Consequently, it is reasonable to counteract the adverse effects of stimuli on exposed vital dentin by mechanical occlusion of the orally patent dentin tubules.

An array of compounds and techniques for blockage of dentinal tubuli has been described and is available in the market both as home-care products and for professional topical applications, such as different oxalate-, phosphate- and carbonate-compounds, fluoride varnishes, liners, dentin adhesives, mouthwashes, and dentifrices⁸.

With the frequent introduction of new desensitizing agents, often made available to the dental market without being clinically proven, suitable in vitro test procedures gain importance as predictive tools for clinical efficacy. Dentin permeability trials were often used as in vitro methods to evaluate the efficiency of desensitizing compounds using fluid filtration methods through dentin discs or crown segments⁸,⁹,¹⁰. Such methods were easily performed and offered clues to understanding the mechanisms of action under given experimental conditions. However, the testing method had a paramount effect on the result of in vitro trials. Human dentin disc models, as originally introduced in 1981 by Greenhill and Pashley⁸ are still frequently used with some modifications to assess hydraulic conductance as a measure for the ease of fluid flow through dentin⁸,¹⁰, however a relatively high pressure should be applied the dentin disc to obtain a clear results and this high pressure could not be assumed to occur in vivo. Recently a new fluid flow measurement using a highly sensitive micro digital flow meter was introduced, which could determine a little flow quantity exactly under pressure in vivo; therefore, precision and reliability are improved in comparison with a previous fluid flow measurement.
method markedly\(^{16}\).

A recently introduced desensitizing agent (Teethmate\(^{TM}\) Desensitizer; TD: Kuraray Noritake Dental, Tokyo, Japan) is a powder blend containing anhydrous dicalcium phosphate (DCPA) and tetracalcium phosphate (TTCP) that is mixed with an aqueous solution to form a paste that upon application is claimed to occlude open dentinal tubules.

Clinical requirements for the desensitizing agents include a continuous occlusion of dentinal tubules. Due to the higher solubility of DCPA and TTCP in water the less soluble hydroxyapatite or precursor phosphates are precipitated by dissolution-precipitation reactions\(^{17-19}\). Several \textit{in vitro} investigations\(^{14,15,20-23}\) and one double-blinded randomized controlled 6 month clinical trial\(^{24}\) have proven the efficacy of TD. However, the artificial saliva employed for the storage liquid has the ability of continuous attenuation of the dentin permeability\(^{22,25,26}\). These open questions concerning the effects of water or in artificial saliva storage of TD- or water-treated dentin specimens need to be elucidated in more detail.

Aim of this \textit{in vitro} study was to investigate the effect of permeability reduction through human coronal dentin slices after application of TD or water and storage in artificial saliva or water, respectively, using a split-chamber device equipped with a highly sensitive digital flowmeter. Furthermore, the extent of occlusion of dentinal tubules was investigated using scanning electron microscopy (SEM). The null hypothesis was that there are no differences in reduction of dentin permeability and obturation of dentin tubular orifices neither following the two specimen treatments nor as result of the two storage conditions.

**MATERIALS AND METHODS**

**Teeth and dentin slice preparation**

Eighty-seven caries-free human third molars were extracted for surgical reasons and stored for less than 1 month in deionized water at room temperature. The Ethics Committees of the Dental Faculty of Tohoku University (Approval No, 26-10; 2015/3/9) approved to use of these teeth for the present investigation. Coronal 1.3 mm thick dentin slices were cut perpendicular to the long axis of the teeth using a diamond wafer saw microtome (Model SP 1600, Leica Microsystems, Wetzlar, Germany) under water-cooling. The first section was made as close as possible occlusal from the pulp horns and the second section underneath the coronal enamel. Then, the slices were rinsed with tap water and immersed in 0.5 M EDTA solution (pH 7.4) for 2 min ultrasonic cleaning to remove the cutting smear and debris pressed inside the dentinal tubules prior to thorough rinsing with distilled water.

---

![Diagram](image.png)

Fig. 1  a) Schematic presentation of the dentin permeability device: A) column of split chamber, B) O-ring, C) specimen, D) metal retainer, E) liquid flow meter, F) reservoir. Hydraulic pressure was applied through the upper side chamber (arrow). The level of the water surface in the reservoir was maintained at the same height as the specimen.

b) Thermoelectric flow sensor: The asymmetry of temperature profile modulated by the flow is evaluated by using 2 temperature sensors surrounding a central heating element. Temperature difference upstream and downstream can be used for detection of flow velocity.

c) Graphical output of the flow sensor. During the initial part of the measuring period (180 s) the output signal includes often artifact noises. The average value during the following 3 min was accounted for the record.
Dentin permeability device

The schematic diagram of the permeability-testing device is shown in Fig. 1. Each specimen was mounted in a metal ring retainer using self-curing acrylic resin (GC Unifast II No. 3 Pink, LOT: 1111161; GC, Tokyo, Japan). Pilot holes drilled in the metal ring enabled exact reposition of the specimen at each measuring stage. Back and front of the specimen, which the sliced surfaces were faced to the crown side and the pulp side, could be identified by appearance of optical characteristics of dentin. Each mounted dentin disc was clamped between two O-ring sealed chambers in a split chamber device to be placed the pulpal side of dentin disc as the perfusing water side. Water was perfused at 2 kPa nominal pressure through the pulpal side of dentin disc as the perfusing water side. Water was perfused at 2 kPa nominal pressure through the dentin disc from the pulpal side. The resulting fluid flow was measured with a thermoelectric flowmeter (LG16-0150, Sensirion, Staefa, Switzerland (full scale: 7 µL/min) at an interval of 0.1 s as the average fluid flow rate (filtration rate) in µL/min between 3 and 6 min from time of pressurizing. The first 3 min of the measurements were disregarded, since often irregular peaks were noted, probably due to minor air bubbles passing through the capillaries of the dentinal tubules.

The initial flow rate measurement was registered as pretreatment baseline value characteristic for the specimen and served for screening. The specimen was then re-immersed into deionized water. From the 87 specimens screened 40 fulfilled the pre-selected range of 0.5 through 5 µL/min and were thus accepted for the trial. Specimens with baseline permeability higher or lower than the target range were excluded. After additional 7 days of water storage, the definitive registration of the baseline (BL) permeability was made, immediately followed by the predetermined random treatment and storage condition. The BL value was adopted as the fluid flow rate per minute (µL min⁻¹). Converted into hydraulic conductance (Lp), and considered 100% permeability. Hydraulic conductance (Lp) is expressed in µL min⁻¹ (flow rate) cm⁻² (surface area) cm H₂O⁻¹ (hydrostatic pressure). Measurements at each follow-up stage were recorded as the percentage values from the Lp figures at BL (PR%). Thus, each specimen served as its own control. Post-treatment measurements were made after 1 day (22–26 h), 1 week (6–8 days) and 1 month (28 to 32 days).

Experimental procedure

The forty specimens selected were randomly allocated to 4 testing groups (n=10). According to manufacturer information TD (Lot: 000059) paste is produced from a mix of DCPA and TTCP powder with water containing preservative.

In the first group (TD/AS) the freshly mixed TD (one scoop of powder mixed for 15 s with one drop of liquid) was applied with a microbrush, loaded with the paste twice, for totally 60 s under slight rubbing motion before excess slurry was lightly rinsed off with distilled water for 3 s. Then, the specimen was immediately hanged up with a stainless steel hook passing through one of the pilot holes of the specimen’s metal retainer and immersed in artificial saliva (1.5 mmol/L CaCl₂, 0.9 mmol/L KH₂PO₄, 20 mmol/L HEPES, 150 mmol/L NaCl, pH 7.0) in a beaker glass and kept in motion on a magnetic stirrer.

In the second group (TD/DW) the specimens were treated as above with TD, yet stored in distilled water. In the third group (DW/AS) specimens were treated with distilled water, applied with a soaked microbrush for 60 s under slight rubbing motion and soaked in artificial saliva. In the fourth group (DW/DW) specimens were treated with distilled water as above and stored in distilled water.

One investigator treated the specimens allocated to the different groups and another investigator who was unaware of the treatment executed performed all permeability tests. The tests were conducted at ambient laboratory temperature (23±1°C).

Statistical analyses

Since the data of the 4 groups were not normally distributed non-parametric statistical analyses were required. Effects of treatments by storage conditions and storage times were analyzed by Wilcoxon’s signed-ranks test with Bonferroni corrections. Calculations were performed using IBM SPSS, version 22 (IBM SPSS Statistics, Chicago, IL, USA). The level of statistical significance was set as α=0.05.

SEM

Following the final 1 month determination of the flow rate two specimens from each group with a close to average percentage reduction of permeability (PR%) and additional two dentin discs treated with EDTA as the baseline dentin surface were selected and subjected to ascending grades of ethanol prior to immersion in hexamethyldisilazene for 10 min and exposure to ambient room atmosphere for 1 day. The specimens were then mounted on aluminum stubs and sputter-coated with Pt. The treated surfaces were inspected using a scanning electron microscope (VE-8800, Keyence, Osaka, Japan) at 10 kV acceleration and images were obtained at random locations at 1k magnifications. One high-resolution SEM photograph was taken at 10,000 magnification (SU-6600, Hitachi High-Technologies, Tokyo, Japan).

RESULTS

The Table 1 shows the means and standard deviations (n=10) of the hydraulic conductance values by treatment groups and time stages. The BL values for the 4 groups were not significantly different (p>0.05). TD-treated specimens showed gradual decreases in Lp from BL to 1 month of storage, more pronounced for the TD/AS than for the TD/DW group. Specimens treated with DW and stored in AS showed no significant differences in Lp from BL to 1 week, whereas the hydraulic conductance had dropped to 0.01 after 1 month, being not significantly different from the two TD-treated groups after 1 month of storage. Lp values at the four time points of the DW/DW group were not significantly different (p>0.05).
Table 1  Hydraulic Conductance (Lp) µL min⁻¹ cm⁻² cmH₂O⁻¹ (n=10) by treatment groups and time points

| Time point | TD/AS       | TD/DW       | DW/AS       | DW/DW       |
|------------|-------------|-------------|-------------|-------------|
| BL         | 0.23 (0.12) A,a | 0.21 (0.09) A,d | 0.22 (0.06) A,g | 0.30 (0.17) A,i |
| 1 day      | 0.07 (0.07) B,b | 0.15 (0.05) C,e | 0.21 (0.08) C,g | 0.28 (0.16) C,i |
| 1 week     | 0.05 (0.04) D,b | 0.14 (0.05) E,e | 0.21 (0.04) F,g | 0.27 (0.16) F,i |
| 1 month    | 0.00 (0.01) G,c | 0.03 (0.06) G,f | 0.01 (0.01) G,h | 0.36 (0.21) H,i |

Means (S.D.). Means with the same upper-case letters were not significantly different among the 4 conditions at the same time points. Means with the same lower-case letters denote no difference within each of the experimental groups (p>0.05).

Figure 2 illustrates the percentage reduction (PR%) in hydraulic conductance (Lp) relative to the BL figures of each group, which was considered to be 100% permeability. The TD/AS group showed the biggest reduction in PR% to 31.31, 20.43 and 0.87 after 1 day, 1 week and 1 month of storage, respectively. The mean PR% values for the TD/DW group after 1 day and 1 week storage were close to 70% and not significantly different, first after 1 month a very significant reduction to 14.29% was noticed. The DW/AS group showed scarcely a percentage reduction from BL after 1 day and 1 week storage, whereas 1-month storage resulted in 3.18 PR%. PR% for the DW/DW group at the three time points were 93.33, 90.00 and 114.74% and not significantly different from BL (100%).

The SEM photographs in Fig. 3 revealed the control specimen at the BL, the TD- and water-treated dentin surfaces following 1 month of storage in AS and water, respectively. Inspection of the control specimen at the BL displayed all dentinal tubules open and lined with peritubular cuffs of dentin. Intertubular dentin was covered with collagen fibrils left after the EDTA treatment for removal of cutting smear and opening of the dentinal tubules (A).

The entire surface of TD/AS (B) was densely covered...
with mineral deposits; most of them had globular shapes. Apart from several micrometer wide globules fine-grained mineral precipitates were recognizable. No tubular entrances were perceptible.

When stored for 1 month in DW the surface of the TD-treated dentin (C) was characterized by an abundance of globular mineral deposits and very small crystalline precipitates. Almost all tubular entrances were completely obturated. The high-resolution SEM photograph displays starting phosphate elements covered with precipitates of fine particles from the surrounding aqueous environment, supersaturated with Ca and phosphate ions (Fig. 4).

The SEM of dentin treated with DW and stored for 1 month in AS (D) showed a surface deposit layer, heavily cracked presumably due to the vacuum treatment during sputter-coating and/or SEM inspection. In several areas, parts of the crust were lost, revealing underlying dentin covered by another layer of fine mineral deposits. No patent tubules were discovered.

Dentin treated with and stored in DW (E) for 1 month had a similar appearance as the EDTA treated BL specimen (A), yet without superficial organic fiber material present. All dentinal tubules were patent, peritubular dentin cuffs were readily discernible, and the intertubular dentin appeared like regular solid dentin.

**DISCUSSION**

An excellent way to treat hypersensitive dentin lesions might be remineralization, *i.e.* occluding patent dentinal tubules with low solubility minerals, such as hydroxyapatite. This was supposedly the intention when TD, inspired by the work of Ishikawa *et al.* the aim of this *in vitro* study was to investigate the effect of permeability reduction through human coronal dentin after application of TD or water and storage in AS or water, respectively, at several time points during storage periods of 1 month and to visualize surface changes related to the variable conditions. The null hypothesis that there were no differences in reduction of dentin permeability and dentin tubular orifice obturation depending on dentin treatments or storage conditions was rejected.

In the present investigation dentin disc specimens were treated with EDTA, primarily to remove the cutting smear and smear plugs clogging tubular entrances for determination of the specific specimen baseline permeability. Forty dentin disc specimen whose filter rate was 0.5 through 5 µL/min were selected from 87 specimens and were randomly assigned 4 groups. There was no significant difference in the hydraulic conductance among 4 groups at the BL. However, the hydraulic conductance and its standard deviation of the DW/DW group was greater than those of the other groups by chance. The procedure of EDTA treatment can be criticized as collagen fibers may cover dentin following the mild demineralization of the solid dentin surface and that phosphoproteins might hamper mineral crystal growth on the target surface. In contrast, previous *in vitro* trials with phosphate containing desensitizers revealed that dentin disc permeability was greatly reduced, irrespective of the presence of exposed collagen after EDTA treatment. TD contains DCPA and TTCP, starting phosphate mineral species that due to their relatively high solubility in water would readily be transformed to hydroxyapatite or precursor minerals with less solubility in aqueous environment. Upon application of a fresh mix of TD the starting components DCPA and TTCP both eventually partly occluded patent tubules and were distributed on intertubular dentin. Due to dissolution of the starting phosphates the surrounding aqueous environment will within short time be oversaturated relative to hydroxyapatite that will precipitate at nucleation sites, primarily on the surfaces of the starting phosphates (Fig. 4). The permeability reduction data showed that TD-treated dentin resulted in fast PR when stored in AS, to approximately 30, 20 and 1 percent of BL after 1 day, 1 week and 1 month, respectively. This effect could be explained by the enormous increase in nucleation sites for additional apposition of crystals deriving from the surrounding AS that is highly supersaturated with calcium and trivalent phosphate ions. When on the contrary, the TD-treated specimens were stored in distilled water, expectedly the PR took place at a slower path, since exclusively the dissolution-precipitation reaction of the starting phosphate compounds in TD contributed to new hydroxyapatite apposition on the starting phosphates and on natural nucleation sites of the exposed dentin. With increasing coverage of the surfaces of DCPA and TTCP particles with precipitated hydroxyapatite the sites from which further Ca and phosphate could be dissolved...
were reduced. Thus, the entire reaction is decelerated, resulting in 68, 67, and 14% PR after 1 day, 1 week and 1 month, respectively. Morphologically, the tubules were tightly obturated and intertubular dentin showed some apposition of crystalline species. The SEM photograph (Fig. 4) showed at high resolution that starting phosphate crystals were overgrown with fine crystalline deposits. In order to analyze these fine deposits, X-ray diffraction or X-ray crystal structure analysis is useful technique. Thanatvarakorn et al.\(^{29}\) reported that the energy dispersive X-ray spectroscopy analysis of the formed layer by TD indicated the minerals with similar Ca/P ratio to hydroxyapatite. Main components of TD are TTCP and DCPA that are spontaneously transformed into hydroxyapatite or precursor phases. Therefore, these fine crystalline deposits could be presumably hydroxyapatite or precursor phases.

Following treatment of the dentin specimen with distilled water prior to immersion in AS reduction in permeability was hardly noted after 1 day and 1 week, whereas PR was as low as 3% after 1 month. Under this experimental condition the only source for delivery of Ca and phosphate ions is the oversaturated AS solution. The SEM photograph after 1 month of storage in AS revealed a layer of very fine-grained crystal precipitate, that was heavily cracked and locally detached from the underlying dentin, proving that the integration between dentin and overlying deposit was not strong. Clinically, this layer would probably not withstand the acid and mechanical attacks without loosening from the surface. The last of the 4 groups evaluated was a control, where specimens were treated with distilled water and stored in distilled water. Expectedly, there was no significant reduction in permeability, which was also visually confirmed on the SEM photograph, showing open dentinal tubules and no crystal precipitation on intertubular dentin.

The design of the present investigation gave some insight into the mechanism of action of TD under different storage conditions. The pulpal pressure used was close to the physiological pressure of the pulp, namely 2 kPa (around 20 cm H\(_2\)O, as reported by the authors concluded from a sophisticated investigation overemphasizing the reduction in permeability seen from the pulpal site and precipitate as hydroxyapatite, and phosphate ions could also penetrate into the tubules from the pulpal aspect. Thus, from the oversaturated AS Ca and phosphate ions also penetrate into the tubules from the pulpal site and precipitate as hydroxyapatite, overemphasizing the reduction in permeability seen in groups one and three of the trial. In future studies this drawback will be eliminated using a new device for application and storage.

One limitation of our trial was that the specimens were treated without hydrostatic pressure from the pulpal side and that the specimens were kept in the storage solutions with access of the medium from both surfaces and without the 2 kPa pressure maintained from the pulpal aspect. Thus, from the oversaturated AS Ca and phosphate ions could also penetrate into the tubules from the pulpal site and precipitate as hydroxyapatite, overemphasizing the reduction in permeability seen in groups one and three of the trial. In future studies this drawback will be eliminated using a new device for application and storage.

Nevertheless, in agreement with other authors the results obtained seem to indicate that TD has a potential as a topical, biocompatible desensitizing agent\(^{14,15,21,23}\). Initial clinical results from a 6-month randomized controlled trial of TD confirm the expectations\(^{26}\).

**ACKNOWLEDGMENTS**

The authors gratefully acknowledge Kuraray Noritake (Japan) for donation of the materials. The authors acknowledge Dr. Kazuomi IKEDA for statistical calculation. This study was supported by JSPS
CONFLICT OF INTEREST

The authors have no conflict of interest to declare.

REFERENCES

1) Chabansky MB, Gillam DG. Aetiology, prevalence and clinical features of cervical dentine sensitivity. J Oral Rehabil 1997; 24: 15-19.
2) Chabansky MB, Gillam DG, Bulman JS, Newman RN. Prevalence of cervical dentine sensitivity in a population of patients referred to a specialist Periodontology Department. J Clin Periodontol 1996; 23: 989-992.
3) Draenert ME, Jakob M, Kunzelmann KH, Hickel R. The prevalence of tooth hypersensitivity following periodontal therapy with special reference to root scaling. A systematic review of the literature. Am J Dent 2013; 26: 21-27.
4) Canadian Advisory Board On Dentin Hypersensitivity. Consensus-based recommendations for the diagnosis and management of dentin hypersensitivity. J Can Dent Assoc 2003; 69: 221-226.
5) Brännström M. The elicitation of pain in human dentine and pulp by chemical stimuli. Arch Oral Biol 1962; 7: 59-62.
6) Brännström M. A hydrodynamic mechanism in the transmission of pain produced stimuli through the dentin. In: ANDERSEN DJ, editor. Sensory mechanisms in dentin. Oxford: Pergamon Press; 1963. p. 73-79.
7) Porto ICCM, Andrade AKM, Montes MAJR. Diagnosis and treatment of dental hypersensitivity. J Oral Sci 2009; 3: 323-332.
8) Greenhill JD, Pashley DH. The effects of desensitizing agents on the hydraulic conductance of human dentin in vitro. J Dent Res 1981; 60: 686-698.
9) Gillam DG, Mordan NJ, Newman RN. The dentine disc surface: a plausible model for dentin physiology and dentin sensitivity evaluation. Adv Dent Res 1997; 11: 487-501.
10) Pereira JC, Segala AD, Gillam DG. Effect of desensitizing agents on the hydraulic conductance of human dentin subjected to different surface pretreatments: an in vitro study. Dent Mater 2005; 21: 129-138.
11) Duran I, Sengun A, Yildirim T, Ozturk B. In vitro dentine permeability evaluation of HEMA-based (desensitizing) products using split chamber model following in vivo application in the dog. J Oral Rehabil 2005; 32: 34-38.
12) Ishihata H, Kanehira M, Nagai T, Finger WJ, Shimachi H, Komatsu M. Effect of desensitizing agents on dentin permeability. Am J Dent 2009; 22: 143-146.
13) Zhang L, Sun H, Yu J, Yang H, Song F, Huang C. Application of electrophoretic deposition to occlude dentinal tubules in vitro. J Dent 2018; 71: 43-48.
14) Thanatvarakorn O, Nakashima S, Sadr A, Prasunsuttiporn T, Thitthaweerat S, Tagami J. Effect of a calcium-phosphate based desensitizer on dentin surface characteristics. Dent Mater J 2013; 32: 615-621.
15) Han L, Okiji T. Dentin tubule occluding ability of dentin desensitizers. Am J Dent 2015; 28: 90-94.