2. Results

During the observation period, no toxicity to the affected teeth or the surrounding gingiva was observed in any subject.

Table 3 shows changes in post-treatment pain induced by cold air/tactile stimulation. While the mean pre-treatment pain score was 2.00, the mean values at just after the treatment, 1 week after the treatment, and 2 weeks after the treatment were 0.27, 0.30, and 0.47, respectively. Figure 23 demonstrates a prolonged effect of NANOSEAL against cold air/tactile stimulation. When the difference between the intensity of pre-and post-treatment pain was statistically tested by Mann-Whitney U test, a significant improvement of the pain symptoms compared with the preoperative level was observed at each assessment time point ($p < 0.001$). However, an increase in sensation over time, so-called "backsliding," was observed after treatment in 3 patients (10.0%) at 2 weeks after the treatment. Since NANOSEAL was applied only once in this assessment, multiple applications of this desensitizer to the lesion is expected to be helpful in addressing this "backsliding" phenomenon.

Although it is impossible to simply compare the present results with other previous reports involving different assessment subjects and testing methods, the present results suggested that the desensitizing effect of NANOSEAL observed just after the treatment and at 1 week after the treatment was superior to those of "MS Coat" reported by Ishihata et al.[10] and IMPERVABOND reported by Shimizu et al.[11] and that a single application of NANOSEAL would yield an effect superior to that of these conventional products. This may be because NANOSEAL causing no problems upon flowing into the proximal surface or gingival crevice was capable of exhibiting its desensitizing effect over a greater area of the dental surface.

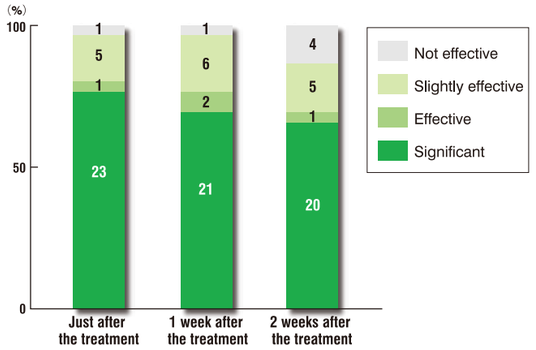

Figure 23
Prolonged effect of NANOSEAL against cold air or tactile stimulation. At each assessment time point, the symptom was found to be significantly improved compared with the pretreatment symptom ($p < 0.001$).

Conclusions

NANOSEAL is capable of sealing open dental tubules by forming nanoparticle deposits after simple 3-step manipulation (mixing, application, and water rinsing). Use of NANOSEAL in dentinal hypersensitivity was found to yield an excellent desensitizing effect just after application. Being excellent in operability (e.g., usable without any particular consideration for the proximal surface or gingival crevice) and exhibiting effects of promotion of the tooth substance and stimulation of remineralization, NANOSEAL is expected to be widely applicable to clinical practice in the future.

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A new material “NANOSEAL” forming an acid-resistant layer on the tooth surface

– Its desensitizing effect and potential power –

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nanoseal®

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Introduction

Dentinal hypersensitivity is a symptom frequently encountered in routine clinical practice and characterized by transient evoked pain induced by slight external stimulation applied to exposed dentin without caries. A variety of approaches for the treatment of dentinal hypersensitivity have been attempted to date, including coverage or closure of dentinal tubules as well as promotion of mineralization in dentinal tubules.

NANOSEAL (Nippon Shika Yakuhin Co., Ltd., see Fig. 1) is a newly developed desensitizer that is excellent in operability and exhibits its effect by reacting with the tooth substance after simple manipulation, i.e., application and subsequent water washing (or rinsing), without any damage to the gingiva. Furthermore, due to its effect of providing acid resistance and promoting remineralization, this material is expected to have a potential for a wide spectrum of clinical applications not limited to the treatment of dentinal hypersensitivity.

Figure 1/
Desensitizer "NANOSEAL"/ (Nippon Shika Yakuhin Co., Ltd.)

Features of NANOSEAL

NANOSEAL is composed of two components: Liquid A, an aqueous dispersion of particulate fluoroaluminosilicate glass crushed to nano-level particles; and Liquid B, an aqueous solution of phosphoric acid. An equivolume mixture of these two components immediately reacts with tooth substance upon application to the tooth surface to form acid-resistant nanoparticle deposits (calcium fluoride, calcium phosphate, calcium silicate, etc.) (Fig. 2).

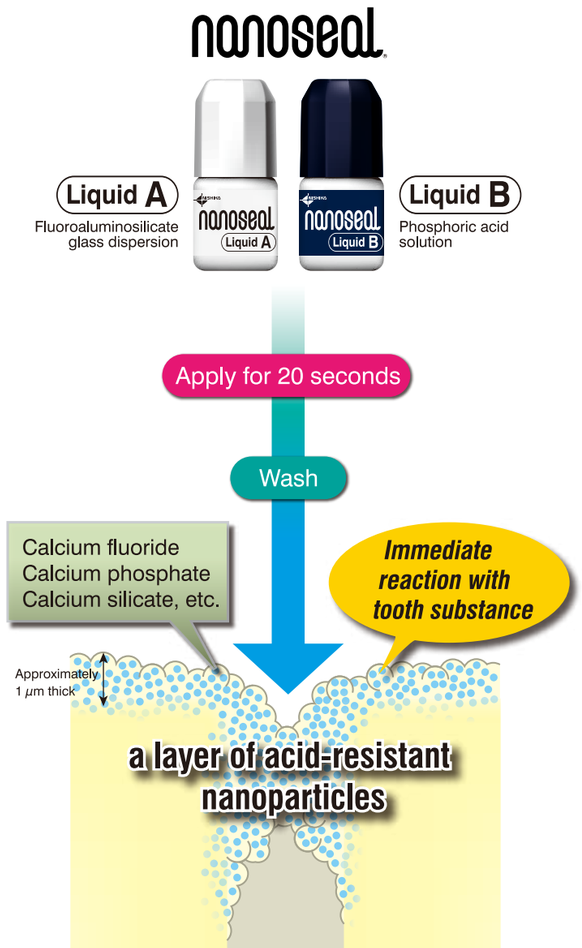

Figure 2
Reaction process of NANOSEAL. Application of the NANOSEAL mixture for 20 seconds induces an immediate reaction on the tooth surface to form acid-resistant nanoparticle deposits.

Unlike resin-based desensitizers, NANOSEAL has a number of excellent clinical advantages: 1) no drying is required before and after application; 2) no light curing and removal of excess cured materials are required; 3) there is no concern of leaving cured materials in the gingival crevice or on the proximal surface (as an obstacle to subsequent dental care); and 4) no etching is required before application to the enamel surface. In addition, since the pH on the tooth surface during NANOSEAL application is approximately 4 (Fig. 3) and completely returns to neutrality after water rinsing, this material can be used more safely than acidulated phosphate fluoride solutions.

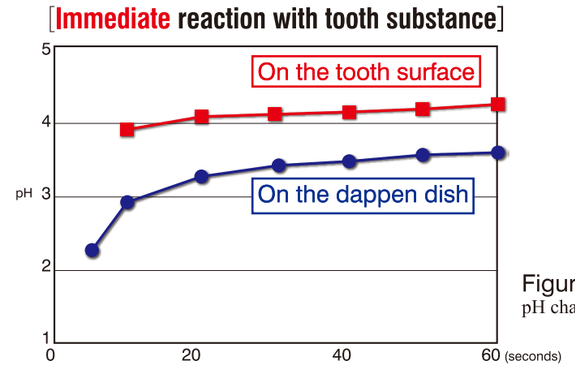

Figure 3
pH change during NANOSEAL application

Versatile effects of NANOSEAL

1. Seal of open dentinal tubules (Fig. 4)

Simple application of NANOSEAL has been confirmed to seal dentinal tubules by forming nanoparticle deposits,[1,2] and a similar phenomenon occurs upon application to the wet tooth surface immediately after water rinsing. The deposited nanoparticles seal the dentinal tubules not by simple deposition on the tooth surface but by integration with the intertubular matrix and inner walls of the dentinal tubule. Reportedly, a single application of NANOSEAL generates a layer of nanoparticle deposits measuring 1–2 μm in thickness, and the thickness of this deposit layer increases to only up to 2–3 μm even after four times of application.[2]

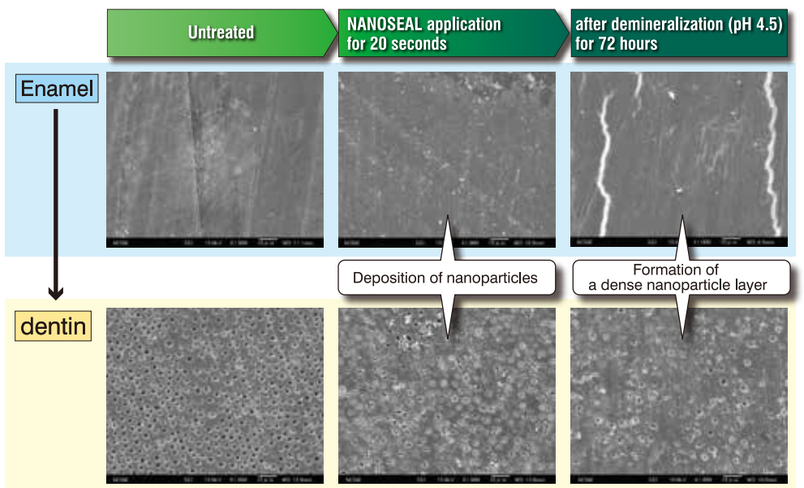

Figure 4
Acid resistance of the NANOSEAL-applied tooth surface.NANOSEAL application generated nanoparticles in both the enamel and the dentin (middle). Demineralization treatment generated a denser nanoparticle layer covering the tooth surface to exhibit excellent acid resistance (right).

2. Acid resistance (Fig. 4)

Scanning electron microscopy (SEM) has revealed that, after the application of NANOSEAL for 20 seconds, the dentin surface was not demineralized by immersion in a demineralizing agent (pH 4.5) for 72 hours.[3)]

In addition, the NANOSEAL-applied enamel specimens were more resistant to acid than those after application of a commercially available acidulated phosphate fluoride solution for 5 minutes, as demonstrated by the QLF technique [1][4, 5)] and they were not demineralized at all after immersion in a cola drink (pH 2.7), a carbonated beverage, for 110 hours to demonstrate amazing acid resistance (Fig. 5). Furthermore, a study using deciduous teeth has confirmed that NANOSEAL exhibits excellent acid resistance under a condition (cola drink: pH 2.7, immersed for 2 hours) specimens undergoing application of an acidulated phosphate fluoride solution (5 minutes) plus subsequent application of CPP-ACP [2] (3 minutes) could not tolerate.[6)]

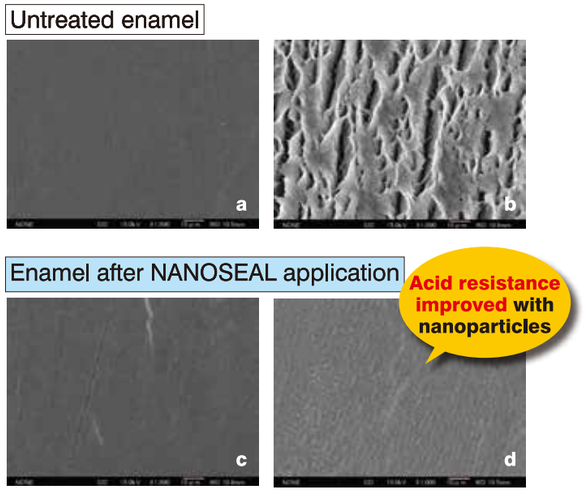

Figure 5
Amazing acid resistance of the NANOSEAL-treated tooth surface to a cola drink. Immersion of untreated enamel (a) in a cola drink (pH 2.7) for 110 hours (4.5 days, 37°C) resulted in exposure of enamel prisms with partial loss of their organized structure (b). In contrast, when NANOSEAL-applied enamel (c) was treated in a similar manner, no change was observed on the NANOSEAL-applied surface (d).

3. Mineralization of demineralized enamel (coverage protection)

It has been reported that application of NANOSEAL to the surface of artificial enamel with incipient caries[2, 4)] and EE surface around brackets for orthodontic treatment[7, 8)] immediately generates a uniform layer of acid-resistant nanoparticles covering and protecting the surface to provide greater mineralization and acid resistance than those achieved with the use of acidulated phosphate fluoride solutions.[4, 5)] Figure 6 shows the enamel surface which was etched with phosphoric acid and to the left half of which NANOSEAL was applied before subsequent water rinsing. A sheen is restored immediately after NANOSEAL application to confirm its effect of mineralization.

4. Promotion of remineralization

A study reported that application of NANOSEAL followed by immersion in an artificial saliva for 10 days exhibited a remineralizing effect approximately two times or greater than that of application of a sodium fluoride solution (900, 9000 ppm F^-) and resulted in remineralization not only on the outmost surface but also in the deep layer of demineralized enamel subsurface lesion (approximately 150 μm in depth).[9)]

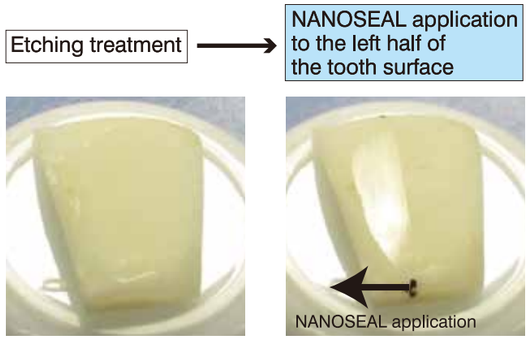

Figure 6
Instant enameling of the EE surface (the left half of the tooth surface). Simple application of NANOSEAL instantly restored a sheen on the EE surface.

A wide spectrum of clinical applications expected for NANOSEAL

Having effects of providing acid resistance and promoting remineralization superior to those provided by conventional materials, NANOSEAL is expected to be applicable not only to desensitization (Figs. 7-14) but also to the following cases:

Potential clinical applications of NANOSEAL: Figs.15-22

White spots on the enamel surface, lesions of mild partial enamel hypocalcification, prevention of erosion of deciduous and immature permanent teeth, reinforcement of the tooth substance in pits and fissures, vicinity of brackets for orthodontic treatment, maintenance of the tooth cervix after prosthetic treatment, etc.

While NANOSEAL has such a rich potential as described above, clinical assessment of its basic desensitizing effect was conducted first.

[A case of complained dentinal hypersensitivity at the mesial proximal surface and tooth cervix]

Figure 7
Teeth 8, 9, 10 and 11 at the first visit

Figure 8
Just after NANOSEAL application. Since NANOSEAL exhibits its effect by reacting with the tooth substance, it does not cause any problem upon contact with the gingiva or the gingival crevice. Manipulation for treatment with NANOSEAL is very simple because it only involves an application to the tooth.

Figure 9
If dried without water rinsing, excess liquid remains as a faint white layer. This layer can be easily wiped off using a cotton ball, etc.

[A case of complained dentinal hypersensitivity of front teeth]

Figure 10
Teeth 24 and 25 at the first visit

Figure 11
Just after NANOSEAL application. The NANOSEAL-applied surface exhibits a slight sheen, which allows easy confirmation of application.

[1] Quantitative light-induced fluorescence
[2] A complex of casein phosphopeptide and amorphous calcium phosphate. Also known as a component of MI Paste.

A wide spectrum of clinical applications expected for NANOSEAL

[A case of hypersensitivity resulting from home whitening]

Figure 12
Teeth 23, 26 and 27 at the first visit

Figure 13
Just after NANOSEAL application.

Figure 14
After water rinsing. NANOSEAL does not affect esthetics.

[A case of application to white spot on the enamel surface]

Figure 15
NANOSEAL was applied to white spot on the enamel surface of tooth 8 at the first visit.

Figure 16
Two months later (after three times of application). NANOSEAL was applied once every 3 weeks.

Figure 17
Four months later (after five times of application). White spot was less distinguishable.

[A case of application to the area around brackets for orthodontic treatment]

Figure 18
Brackets were installed after NANOSEAL was applied once. Then, NANOSEAL was applied again around the brackets installed.

Figure 19
Two months later (after three times of application). NANOSEAL was applied once every 3 weeks.

Figure 20
Four months later (after five times of application).

[A case of application to pits and fissures of the occlusal plane in an attempt of caries prevention]

Figure 21
Teeth 18 and 31 at the first visit.
Coloration of distal pits and fissures was observed with both second molars.

Figure 22
Five months later (after six times of application). NANOSEAL was applied once every 3 weeks.

Desensitizing effect of NANOSEAL

1. Methods for assessment

The subjects of this assessment consisted of 30 patients who underwent dental treatment and were diagnosed with dentinal hypersensitivity at the Department of Dentistry, Hiraka General Hospital between August 2011 and November 2011 (18 males and 12 females; 11 anterior teeth and 19 posterior teeth). Treatment for dentinal hypersensitivity was performed with NANOSEAL and pretreatment and posttreatment pains were assessed.

The absence of caries, pulpitis-like symptoms, and any etiology related to preparation on filling or abutment preparation was confirmed by pretreatment examination.

To assess the efficacy of NANOSEAL, pain was generated by either a cold air stimulation for 3 seconds with an air syringe placed at a distance of approximately 1cm from the lesion or a tactile stimulation using the tip of a dental explorer. The intensity of pain was evaluated according to the assessment criteria shown in Table 1.

The test tooth was cleaned with a brush cone, followed by water rinsing and drying. After application of a preliminary dry field technique with a piece of cotton roll, NANOSEAL was applied to the lesion for 20 seconds. After the application, the treatment was completed by additional water rinsing and drying. The efficacy was assessed immediately, 1 week and 2 weeks after the treatment.

The efficacy was assessed on a 4-level scale (not effective, slightly effective, effective, significant) according to the criteria shown in Table 2.

Table 1
Criteria for the assessment of pain induced by cold air or tactile stimulation

0: Feel no pain
1: Feel minimal pain
2: Feel mild pain (tolerable pain)
3: Feel strong pain (intolerable pain)

Table 2
Criteria for the assessment of efficacy

Not effective	No change in pain score
Slightly effective	improvement of pain score by one level (3→2, 2→1)
Effective	improvement of pain score by two levels (3→1)
Significant	improvement of pain score to zero (3→0, 2→0, 1→0)

Table 3
Change in pain induced by cold air or tactile stimulation after treatment (in 30 subjects)

	3→2	3→1	2→0	2→1	2→2	1→0	1→1
Just after the treatment	1	1	21	4	1	2	0
1 week after the treatment	0	2	19	6	1	2	0
2 weeks after the treatment	1	1	19	4	3	1	1