

IN VITRO EVALUATION OF EXPERIMENTAL FLUORIDE TAPE IN INHIBITION OF ENAMEL DEMINERALIZATION

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Abstract

The aim of this *in vitro* study was to evaluate the effectiveness of experimental 2.26% fluoride-polyvinyl alcohol (F-PVA) tape in inhibition of enamel demineralization using enamel surface microhardness (SMH) analysis and scanning electron microscopy (SEM) examination.

Enamel specimens (n=60) randomly assigned to four groups: control group, F-PVA tape group, fluoride varnish (F-varnish) group, casein phosphopeptide-amorphous calcium phosphate (CPP-ACFP) group. After topical application, pH-cycling was processed. Then, SMH was measured and the percentage loss of surface microhardness (%SML) was calculated. For the SEM examination, five sample specimens in each group were treated and the morphologic character was evaluated.

After pH-cycling, the SMH values of the enamel specimens of F-PVA tape and F-varnish group were significantly higher than that of CPP-ACFP group, there was no significant difference between F-PVA tape and F-varnish group. With SEM examination, enamel surfaces in the F-PVA tape group and F-varnish group showed numerous spherical and ovoid crystals formed on the enamel surface were also observed. The density of crystals was higher than that of both control group and CPP-ACFP group.

F-PVA tape is effective in inhibition of enamel demineralization. Also, F-PVA tape's inhibition of enamel demineralization is comparable to that of F-varnish and greater than that of CPP-ACFP.

Key words : Fluoride tape, PVA tape, Enamel demineralization

I . Introduction

Demineralization and remineralization are dynamic processes in the initiation, progression, and reversal of dental caries. Signs of the caries process cover a continuum from the first molecular changes in the apatite crystals of the tooth, to a visible white-spot lesion, through to dentin involvement and eventual cavitation. Progression through these stages requires a continual imbalance between pathologic and protective factors that results in the dissolution of apatite crystals and the net loss of calcium, phosphate, and other ions from the

tooth. Therefore, regulation of the demineralization-remineralization balance is a key to prevention of dental caries. A goal of modern dentistry is to manage non-cavitated carious lesions non-invasively through remineralization in an attempt to prevent disease progression and thereby improve esthetic, strength, and function of tooth¹⁻³⁾.

Fluoride use has been credited with playing a major role in the reduction of dental caries in the pediatric population. In fact, the proportion of people entering adulthood without caries has increased dramatically⁴⁻⁶⁾. The widespread use of fluoride in dentifrices, mouthrins-

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es, fluoridated varnishes and gels all have helped to reduce the prevalence of dental caries^{7,8)}. To improve convenience and effectiveness of fluoride treatment while minimizing the adverse effect of overdose-uptake, various forms of fluoride delivery materials have been developed. Fluoride varnish has been used as a professional topical fluoride agent and adheres to the tooth surface, which potentially prevents complications from children's swallowing but it has major disadvantages such as stickiness, bitter taste, and unesthetic appearance after application. To overcome those disadvantages, we have developed a fluoride-polyvinyl alcohol tape (F-PVA tape) as an experimental fluoride delivery material.

The discovery of PVA dates back to 1924, when a PVA solution was obtained by saponifying poly (vinyl ester) with caustic soda solution. PVA has excellent physical properties, such as viscosity, film forming, emulsifying, dispersing powder, adhesive strength, tensile strength, and flexibility. PVA is also resistant not only to water, but also to oil, grease, and solvents. Based on these versatile properties, PVA has been widely used, especially in fabric and paper sizing, fiber coating, adhesives, emulsion polymerization, films for packing and farming, and the production of polyvinyl butyral. PVA has also

been used in manufacturing medical materials such as hydrogel to mimic soft tissue, drug delivery system, biosensor, bioreactor, antitumor agent, hemostatics. PVA is non-toxic to organisms and has biodegradability. Most of the PVA-degraders are Gram-negative bacteria belonging to the genus *Pseudomonads* and *Sphingomonads*, but Gram-positive bacteria with PVA-degrading abilities have also been reported⁹⁻¹¹⁾.

This *in vitro* study was designed to evaluate the effectiveness of experimental F-PVA tape in inhibition of enamel demineralization, through enamel surface microhardness (SMH) analysis and scanning electron microscopy (SEM) examination.

II. Materials and methods

1. Study design

The study design is shown in Fig. 1.

2. Preparation of F-PVA tape

PVA (10 g) and polyacrylic acid (5 g) were added to 85 g of distilled water and the mixture was stirred for 2

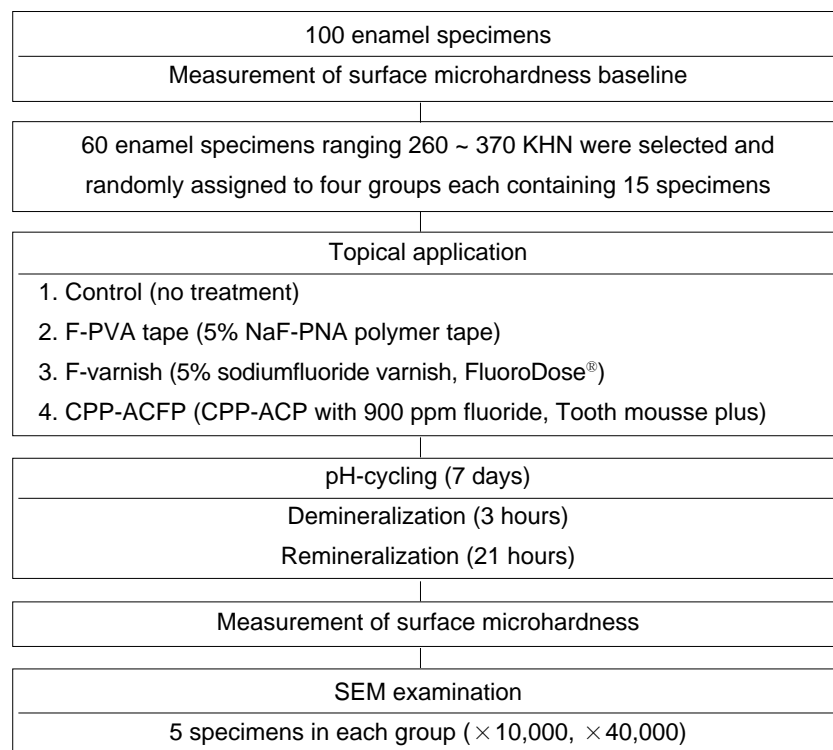


Fig. 1. Illustration of the study design.

hours at 85°C. Polyethylene glycol (3 g), as a plasticizer, and NaF (0.95 g) were added progressively and stirred for 2 hours at 85°C. Then, the mixture was poured onto a glass plate, and spread to a uniform in width (20 μ m) using an applicator, and then dried for 24 hours at 60°C (Fig. 2)¹²⁾. The F-PVA tape is shown in the Fig. 3.

3. Specimen preparation

One hundred enamel blocks (5 mm \times 5 mm) were prepared from bovine incisor teeth, which were freshly extracted. The teeth were cut using diamond cutting disks (Komet, USA). Custom made plastic cylindrical molds were prepared and self cured acrylic resin (Dentsply International Inc., USA) was poured on it; then each enamel block was embedded in, on top partially set, and allowed to set. Specimens were then polished flat progressively with 400, 800, 2400 and 4000 grit silicon carbide sandpapers (R&B Inc., Korea) on a

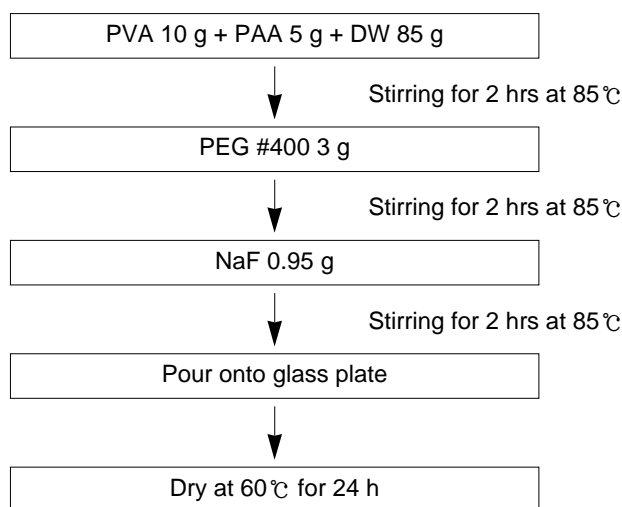


Fig. 2. The procedure for preparation of F-PVA tape.

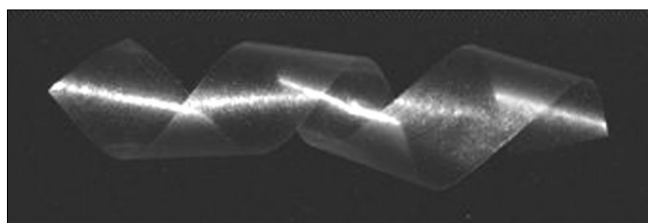


Fig. 3. The experimental F-PVA tape.

rotating polishing machine (METPOL-1, R&B Inc., Korea) and stored in distilled and deionized water.

Enamel specimens (n=60) with microhardness ranging from 260 to 370 Knoop hardness number (KHN) were pooled and randomly assigned to four groups, each containing fifteen specimens.

4. Topical application of agents

The following four experimental groups were used in this study:

(1) No treatment (control group). No treatment was given to the enamel surface, and the teeth were kept in the distilled and deionized water for 6 hours.

(2) 2.26% F-PVA tape (F-PVA tape group, developed material experimentally). A piece of tape, sized 5 mm \times 5 mm, was put onto each enamel specimen, and soaked with distilled and deionized water using microbrush for fluoride ions to dissolve from it and act at the enamel surface for 6 hours. Then it was delicately removed from the enamel surface using cotton tips immersed in deionized water, without rubbing.

(3) 2.26% fluoride varnish (F-varnish group, FluoroDose[®], Centrix Inc., USA). A thin layer of fluoride varnish was applied using a microbrush, left to act at the enamel surface for 6 hours, and then delicately removed from the enamel surface using cotton tips immersed in deionized water, without rubbing. No chemical substances were used for the removal of the varnish in order to not alter the enamel surface.

(4) Casein phosphopeptide-amorphous calcium fluoride phosphate (CPP-ACFP group, GC Tooth mousse plus[™], Recaldent, GC Corp., Japan). A thin layer of CPP-ACFP creme was applied using a microbrush, left undisturbed for 5 minutes and then washed with deionized water. Specimens in this group underwent the same application process twice a day (8:00 am, 8:00 pm) as recommended in the product manual for 7 days of pH-cycling.

5. pH-cycling

A pH-cycling regimen included alternative demineralization (3 hours) and remineralization (21 hours) for 7 days. Using separate containers, the specimens were immersed (30 mL/specimen) in the demineralizing solution [2.2 mM Ca(NO₃)₂, 2.2 mM KH₂PO₄, 50 mM acetic acid, pH 4.5] at 37°C, for 3 hours. After thorough rinsing with

deionized water and careful drying, the specimens were stored (15 mL/specimens) in remineralizing solution [1.5 mM Ca(NO₃)₂·4H₂O, 0.9 mM NaH₂PO₄·2H₂O, 150 mM KCl, 0.1 mM Tris buffer, 0.03 ppm F, pH 7.0] at 37°C, for 21 hours. The demineralizing and remineralizing solutions were changed every cycle¹³⁻¹⁵.

6. Assessment of surface microhardness (SMH)

Enamel demineralization was measured as surface softening with a Knoop microhardness diamond in different regions of the specimens (Knoop diamond, 100 g, 5 s, HMV 2; Shimadzu Corporation, Tokyo, Japan) at baseline and after pH-cycling. All readings were performed by the same examiner using the same calibrated machine. In each reading, four indentations, at least 100 μm apart, were made and their average was taken to represent the specimen's hardness value. Additionally, the percentage loss of surface microhardness was calculated using the following calculation^{16,17}:

$$\%SML = 100 (KHN_{(baseline)} - KHN_{(after\ pH-cycling)}) / KHN_{(baseline)}$$

7. SEM examination

For the SEM examination, five sample specimens in each group were treated. Air-dried sample specimens were sputtered with platinum, resulting in platinum coating. Then, the shapes of the enamel surface were evaluated with SEM (S4700, Hitachi, Japan). For comparison of the morphologic character of the enamel surface, sound and demineralized enamel were also examined. For the latter, five enamel specimens were immersed in demineralizing solution for 21 hours as the same period other experimental groups had been immersed in it throughout the pH-cycling.

8. Statistical analysis

All data were processed by SPSS 17.0 software. The SMH values were compared at the different time intervals in each group with the paired samples *t*-test at a significance level of 0.05. The effects of the F-PVA tape, F-varnish, and CPP-ACFP on the changes in the enamel SMH were analyzed using one-way ANOVA and Student-Newman-Keuls post hoc test at a significance level of 0.05.

III. Results

1. Surface microhardness

The average SMH values of the surface enamel in each group measured at the different time intervals during the treatment are shown in Table 1. The pH-cycling process for 7 days significantly reduced SMH in each group. The SMH values at the baseline were not significantly different among the experimental groups. Table 2 shows the SMH values and %SML among the groups. After pH-cycling, enamel specimens treated with remineralizing agents (F-PVA tape, F-varnish, and CPP-ACFP) presented significantly higher SMH and lower %SML values in comparison to the control group. The SMH values of the enamel specimens of the F-PVA tape and the F-varnish group were significantly higher than that of the CPP-ACFP group. Also, there was no significant difference between F-PVA tape group and F-varnish group. Regarding %SML, the values obtained in the F-PVA tape and F-varnish group were significantly lower than that of CPP-ACFP group.

2. SEM morphological characters

The typical SEM images of the enamel surface in the different groups are shown in Fig. 4 and Fig. 5. Sound enamel has an orderly arranged rod appearance and enamel crystals are homogeneously arranged with a

Table 1. Surface microhardness at baseline and after pH-cycling in each group (mean ± SD)

Group	SMH (baseline)	SMH (after pH-cycling)	p-value
Control	303.62 ± 25.34	123.00 ± 20.00	0.000
F-PVA tape	304.39 ± 36.03	178.52 ± 20.60	0.000
F-varnish	306.75 ± 35.90	173.57 ± 16.71	0.000
CPP-ACFP	322.63 ± 25.93	166.33 ± 15.45	0.000

Table 2. Analysis of surface microhardness and %SML (mean ± SD)

Group	SMH (baseline)	SMH (after pH-cycling)	%SML
Control	303.60 ± 25.34 ^a	123.00 ± 20.00 ^a	59.27 ± 4.25 ^a
F-PVA tape	304.39 ± 36.03 ^a	178.52 ± 20.60 ^b	40.80 ± 5.83 ^b
F-varnish	306.75 ± 35.90 ^a	173.57 ± 16.71 ^b	42.73 ± 6.71 ^b
CPP-ACFP	322.63 ± 25.93 ^a	166.33 ± 15.45 ^c	48.13 ± 8.97 ^c

^{a,b,c} Different letters in each column indicate significant differences among groups by Student-Newman-Keuls post hoc test (*p* < 0.05).

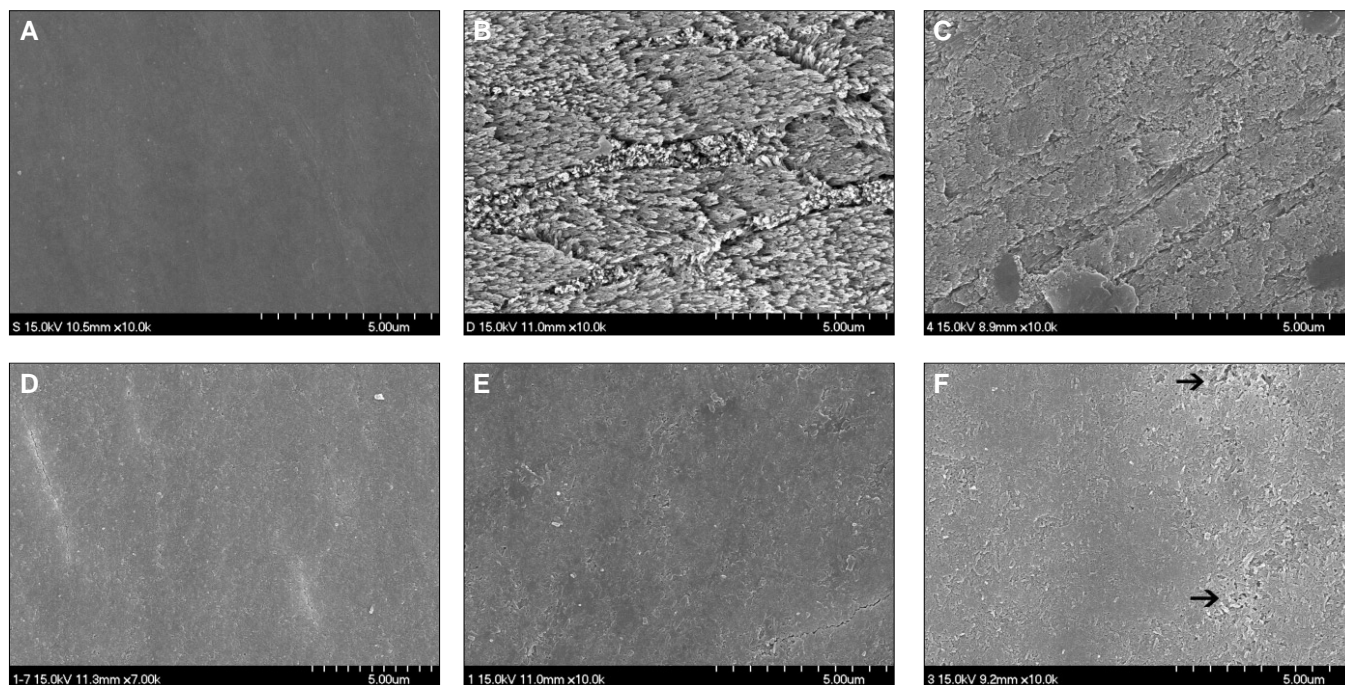


Fig. 4. The SEM images of the enamel surfaces in each group ($\times 10,000$).

(A) Sound enamel : enamel rods are orderly arranged, (B) After demineralization : interrod and intercrystal spaces are prominent, (C) Control : interrod spaces are discernable, (D) F-PVA tape : enamel surface shows mild irregularity, (E) F-varnish : enamel surface shows mild irregularity and it is similar with that of F-PVA tape, (F) CPP-ACFP : the irregularity of enamel surface was more prominent than in F-PVA tape and F-varnish group, and some pot-holes were observed (arrows).

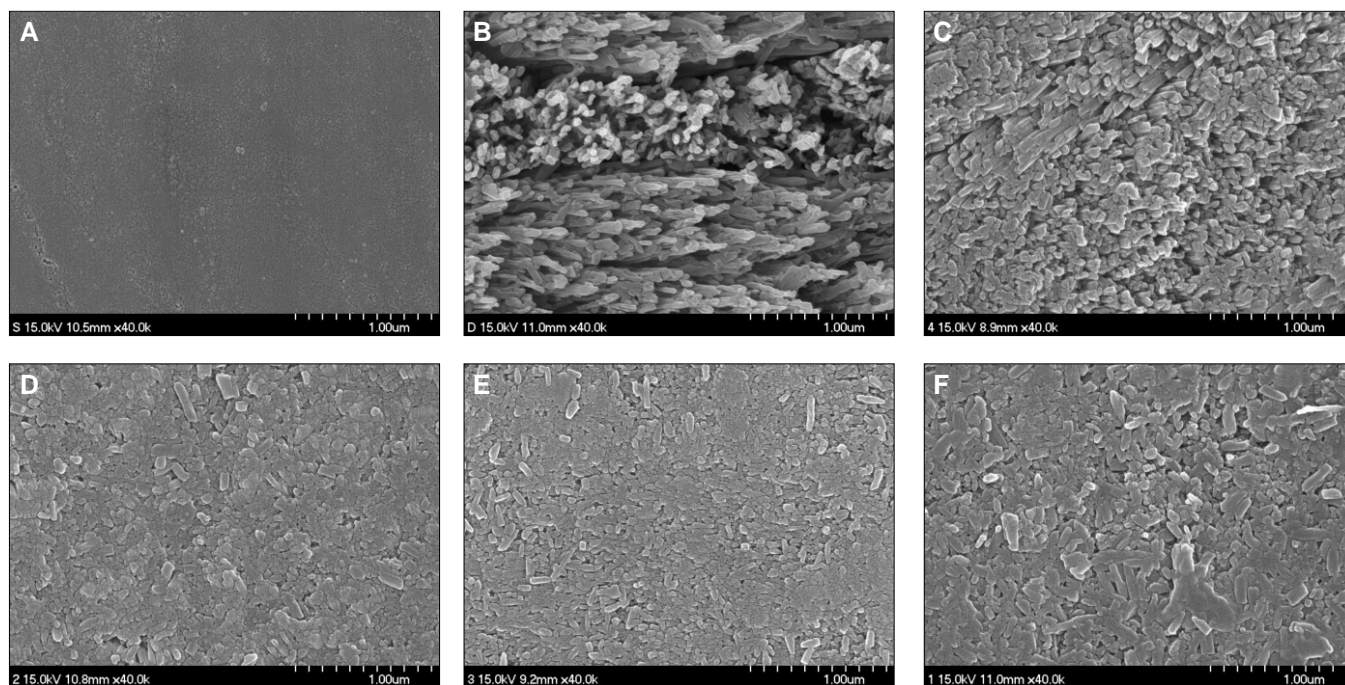


Fig. 5. The SEM images of the enamel surfaces in each group ($\times 40,000$).

(A) Sound enamel : enamel crystals were homogeneously arranged with a clear outline, (B) After demineralization : demineralized enamel had a smaller number of enamel crystals and interrod and intercrystal spaces were very prominent, (C) Control : interrod spaces were discernable in low magnification, and the density of enamel crystals was lower than in other groups, (D) F-PVA tape : numerous spherical and ovoid crystals formed on the enamel surface were observed, and the density of crystals was higher than that of control group (E) F-varnish : numerous spherical and ovoid crystals formed on the enamel surface were observed, and it is similar with that of F-PVA tape, (F) CPP-ACFP : Enamel crystals were irregularly arranged with variable widths and some were fused together and showed obvious intercrystal spaces.

clear outline. For comparison, the surfaces of the demineralized enamel were also examined. They were immersed in demineralizing solution for 21 hours, which is the same period other experimental groups had been immersed in demineralizing solution throughout the pH-cycling. Demineralized enamel has a smaller number of enamel crystals and the interrod and intercrystal spaces are very prominent. In the control group, the interrod spaces were discernable in low magnification and the density of enamel crystals was lower than in other groups. In the F-PVA tape group, enamel surface showed mild irregularity in general and numerous spherical and ovoid crystals formed on the enamel surface were observed. The density of crystals was higher than that of demineralized specimens. Similar patterns were observed in the F-varnish group. In the CPP-ACFP group, the irregularity of the enamel surface was more prominent than in F-PVA tape and F-varnish group and some potholes were observed. Enamel crystals were irregularly arranged with variable widths and some were fused together and had obvious intercrystal spaces.

IV. Discussion

The mineral loss or gain in the enamel as a result of demineralization or remineralization can be measured as changes in the enamel surface microhardness. The indentation hardness test with either the Knoop indenter or the Vicker indenter has been used for measurements of initial enamel hardness, enamel softening after demineralization, and enamel hardening after remineralization. Both these indenters are suitable for hardness testing of nonmetallic materials. The measurement of the Knoop long diagonal is less affected by elastic recovery than the short diagonal or equal diagonals of the 136° diamond pyramid of the Vicker indenter. The Knoop hardness number has been correlated with the volume percentage of the enamel mineral^{11,18,19}.

The study design required a sufficiently flat enamel area to allow enamel SMH measurement. Therefore, the area subjected to the pH-cycling was not the original surface of enamel. Moreover, a decrease in enamel SMH caused by pH-cycling in the polished enamel could be different from that obtained with the uncut enamel. Removal of the outer layer of the enamel made the enamel more susceptible to the demineralization¹.

Based on results from the previous study by ten Cate, the pH-cycling model was composed of 3-hour deminer-

alization and 21-hour remineralization. The demineralization period was designed to simulate the duration of demineralization (low cariogenic challenge) that occurs in the oral cavity²⁰. The composition of demineralizing solution was as follows: 2.2 mM $\text{Ca}(\text{NO}_3)_2$, 2.2 mM KH_2PO_4 , 50 mM acetic acid (pH 4.5)¹⁴. The composition of the remineralizing solution was as follows: 1.5 mM $\text{Ca}(\text{NO}_3)_2 \cdot 4\text{H}_2\text{O}$, 0.9 mM $\text{NaH}_2\text{PO}_4 \cdot 2\text{H}_2\text{O}$, 150 mM KCl, 0.1 mM Tris buffer, 0.03 ppm F (pH 7.0)¹⁵.

Ideally, remineralizing agents need to rapidly precipitate on the partially demineralized tooth structure and transform into a more stable, less acid-soluble apatite than the hard tissue being replaced. They would need to do this in the presence of saliva and before the next acid challenge comes in contact with the newly precipitated mineral. If the mineral phase that is formed is soluble in saliva or under acid conditions, it will be rapidly lost. On the other hand, mineral that is taken up by the enamel may serve as a reservoir that could be released into fluid phase surrounding the enamel crystals during a caries attack and serve as a substrate for subsequent remineralization²¹.

One of the important and well-documented methods for reducing dental caries is fluoride. Fluoride is known to reduce caries in three ways: inhibiting bacterial metabolism of fermentable carbohydrates, enhancing remineralization by the incorporation of available fluoride into the tooth structure during acid attacks, and reducing the tooth's solubility during subsequent acid attack²². The widespread use of fluoride in dentifrices, mouthrinses, fluoridated varnishes and gels all have helped to reduce the prevalence of dental caries⁷. Although various modes of delivery for professionally applied fluoride exist, one form has emerged that combines caries prevention efficacy with safety and versatility. The American Dental Association Council on Scientific Affairs recommends fluoride varnish as the only professionally applied fluoride for moderate to high risk patients of all age groups. In addition to demonstrating effectiveness equivalent to fluoride gels, fluoride varnish provides improved safety and acceptability²³. There is ample clinical evidence that biannual application of fluoride varnish decrease dental caries. Repeated applications within a shorter period have been shown to result in a great reduction of caries²⁴.

The experimental F-PVA tape contains 2.26% fluoride similar to the amount in fluoride varnish (FluoroDose®, Centrix Inc., USA). Supposing application of 2 tapes,

sized 1 cm × 12 cm, in maxillary and mandibular arches respectively, the content of fluoride administered from the tape is 2.35 mg and it is about one third of that of FluoroDose® (6.79 mg). As mentioned in the results, the inhibition potential of enamel demineralization of the experimental F-PVA tape is comparable with commercially used fluoride varnish.

Previously, we conducted an experiment to evaluate the fluoride-releasing efficacy of the F-PVA tape as compared with fluoride varnish (CavityShield™, 3M ESPE OMNI Preventive care INC., Bentonville, USA). We measured the concentration of fluoride in saliva samples of subjects, and found fluoride-releasing efficacy of F-PVA tape and it's comparable with that of fluoride varnish. Thus, we speculate that the effect of F-PVA tape is not limited to the buccal surface to which it adheres, and its effect extends to the proximal and occlusal surfaces^{12,26}.

The tape is transparent and therefore esthetic after application. It does not cause any discomforts associated with fluoride varnish such as stickiness or bitter taste. Moreover, the tooth surface does not need to be dried before application of the F-PVA tape since saliva on the tooth surface can help the F-PVA tape to adhere to the tooth. Although F-PVA tape does not have adhesive property itself, when it is moistened with saliva it can adhere to the tooth surface. So, the application procedure is simple. F-PVA tape provides improved safety and acceptability. It is possible to use it not only in professional fluoride treatment, but also in home-use.

Casein phosphopeptide-amorphous calcium fluoride phosphate (CPP-ACFP) was used as another remineralizing agent. For every 2 fluoride ions, 10 calcium ions and 6 phosphate ions are required to form one unit cell of fluorapatite [Ca₁₀(PO₄)₆F₂]. Hence, on topical application of fluoride ions, the availability of calcium and phosphate ions can be the limiting factor for net enamel remineralization to occur. Tooth Mousse™ contains 10%w/w CPP-ACP nanocomplex. This product has been used clinically in several published reports for successful non-invasive treatment of mild to moderate fluorotic lesions and for the reversal of early caries and also for caries stabilization²⁷. According to an *in vitro* study by Zhang Q. *et al.*¹, the casein phosphopeptide-amorphous calcium phosphate (CPP-ACP) creme is effective in remineralizing early enamel lesion of primary teeth, a little more effective than 500 ppm NaF. On the other hand, Lata S. *et al.*¹³, concluded that CPP-ACP creme is effective, but

to a lesser extent than fluoride (Fluoroprotector, Ivoclar Vivadent, containing 1000 ppm NaF) in remineralizing early enamel caries at surface level. CPP-ACFP is a mixture of CPP-ACP and 900 ppm fluoride, and according to some authors, it is more effective in remineralization of enamel than CPP-ACP^{27,28}. However, there has been no study comparing the efficacy of CPP-ACP (or CPP-ACFP) with high-concentration fluoride.

As a result of this *in vitro* study, CPP-ACFP was observed to be less effective than experimental F-PVA tape and fluoride varnish in inhibition of enamel demineralization. Calcium and phosphate ions were contained in the demineralizing and remineralizing solutions used in pH-cycling, so we speculate that fluoride ion was the critical factor in the inhibition of enamel demineralization in the calcium- and phosphate-rich circumstance. Different application methods of each remineralizing agent might affect the results. In F-PVA tape and F-varnish group, after application of the agent, authors left them for 6 hours to act on the enamel surface. On the other hand, enamel specimens in CPP-ACFP group entered pH-cycling after just a 5-minute application. However, according to a previous study design applying fluoride varnish for 24 hours to evaluate the effect of fluoride varnish^{16,17}, 6 hours isn't long relatively. We applied CPP-ACFP on the enamel specimens twice a day during pH-cycling to simulate the normally recommended daily oral prophylaxis. And we should consider that fluoride varnish is recommended at least twice a year and CPP-ACP (or CPP-ACFP) is recommended twice a day²⁹. In this study, the period of pH-cycling was 7 days, and thus the authors could evaluate short-term effect of F-PVA tape and other remineralizing agents. Considering that CPP-ACFP contains low-level fluoride and is recommended twice a day, 7 days might be relatively short for CPP-ACFP to act sufficiently. So, supposing that this study goes for long period, the result of CPP-ACFP group may be better than that of this study, so the effect of different application methods may be inconsiderable. Further study is needed to evaluate long-term effects of F-PVA tape along with clinical evaluation to overcome the limitations of *in vitro* study.

V. Conclusion

The aim of this *in vitro* study was to evaluate the effectiveness of experimental 2.26% fluoride-polyvinyl alcohol (F-PVA) tape in inhibition of enamel demineral-

ization using enamel surface microhardness (SMH) analysis and scanning electron microscopy (SEM) examination.

The SMH values of the enamel specimens of the F-PVA tape and the F-varnish group were significantly higher than that of the CPP-ACFP group. Also, there was no significant difference between F-PVA tape group and F-varnish group. Regarding %SML, the values obtained in the F-PVA tape and F-varnish group were significantly lower than that of CPP-ACFP group.

In SEM examination, enamel surface in F-PVA tape group showed mild irregularity in general and numerous spherical and ovoid crystals formed on the enamel surface were observed. The density of crystals was higher than that of demineralized specimens. Similar patterns were observed in the F-varnish group.

F-PVA tape is effective in inhibition of enamel demineralization. The inhibition potential of enamel demineralization of F-PVA tape is comparable with that of fluoride varnish and greater than that of CPP-ACFP. With the significant advantages of excellent physical properties, ease of application, and improved safety, F-PVA tape can be used not only for professional treatment, but also in a home-use delivery system.

References

- Zhang Q, Zou J, Yang R, et al. : Remineralization effects of casein phosphopeptide-amorphous calcium phosphate crème on artificial early enamel lesions of primary teeth. *Int J Paediatr Dent*, 21:374-381, 2011.
- Cochrane NJ, Cai F, Huq NL, et al. : New approaches to enhanced remineralization of tooth enamel. *J Dent Res*, 89:1187-1197, 2010.
- Borges BC, de Souza Borges J, de Araujo LS, et al. : Update on nonsurgical, ultraconservative approaches to treat effectively non-cavitated caries lesions in permanent teeth. *Eur J Dent*, 5:229-236, 2011.
- Brunelle JA, Carlos JP : Recent trends in dental caries in U.S. children and the effect of water fluoridation. *J Dent Res*, 69:723-727, 1990.
- Lang WP, Weintraub JA, Choi C, et al. : Fissure sealant knowledge and characteristics of parents as a function of their child's sealant status. *J Public Health Dent*, 48:133-137, 1988.
- Tinanoff N : Dental caries risk assessment and prevention. *Dent Clin North Am*, 39:709-719, 1995.
- Salar DV, García-Godoy F, Flaitz CM, et al. : Potential inhibition of demineralization in vitro by fluoride-releasing sealants. *J Am Dent Assoc*, 138:502-506, 2007.
- 권호근, 김백일, 이영희 등 : 불소치약 사용후 시간 변화에 따른 구강내 타액의 불소농도변화에 관한 연구. *대한구강보건학회지*, 20:555-567, 1996.
- Kawai F, Hu X : Biochemistry of microbial polyvinyl alcohol degradation. *Appl Microbiol Biotechnol*, 84:227-237, 2009.
- Jiang S, Liu S, Feng W : PVA hydrogel properties for biomedical application. *J Mech Behav Biomed Mater*, 4:1228-1233, 2011.
- 최준호 : 폴리비닐알콜 및 셀룰로오스계 혼합 고분자를 이용한 항균 및 분해도 조절 연구. *광주, 조선대 대학원*, 2, 2011.
- 임성옥, 이상호, 이난영, 박승효 : 불소를 함유한 PVA 고분자 접착 테잎의 불소 유리 효과. *대한소아치과학회지*, 38:327-336, 2011.
- Lata S, Varghese NO, Varughese JM : Remineralization potential of fluoride and amorphous calcium phosphate-casein phospho peptide on enamel lesions: An in vitro comparative evaluation. *J Conserv Dent*, 13:42-46, 2010.
- Cheng L, ten Cate JM : Effect of *Galla chinensis* on the in vitro remineralization of advanced enamel lesions. *Int J Oral Sci*, 2:15-20, 2010.
- Magalhães AC, Stancari FH, Rios D, et al. : Effect of an experimental 4% titanium tetrafluoride varnish on dental erosion by a soft drink. *J Dent*, 35:858-861, 2007.
- Murakami C, Bönecker M, Corrêa MS, et al. : Effect of fluoride varnish and gel on dental erosion in primary and permanent teeth. *Arch Oral Biol*, 54:997-1001, 2009.
- Delbem AC, Bergamaschi M, Sasaki KT, et al. : Effect of fluoridated varnish and silver diamine fluoride solution on enamel demineralization: pH-cycling study. *J Appl Oral Sci*, 14:88-92, 2006.
- Featherstone JD, ten Cate JM, Shariati M, et al. : Comparison of artificial caries-like lesions by quantitative microradiography and microhardness profiles. *Caries Res*, 17:385-391, 1983.
- Meredith N, Sherriff M, Setchell DJ, et al. : Measurement of the microhardness and Young's modulus of human enamel and dentine using an indentation technique. *Arch Oral Biol*, 41:539-545, 1996.

20. ten Cate JM, Duijsters PP : Alternating demineralization and remineralization of artificial enamel lesions. *Caries Res*, 16:201-210, 1982.
21. Zero DT : Dentifrices, mouthwashes, and remineralization/caries arrestment strategies. *BMC Oral Health*, 6:S9, 2006.
22. Gibson G, Jurasic MM, Wehler CJ, et al. : Supplemental fluoride use for moderate and high caries risk adults: a systematic review. *J Public Health Dent*, 71:171-184, 2011.
23. Quock RL, Warren-Morris DP : Fluoride varnish: the top choice for professionally applied fluoride. *J Mich Dent Assoc*, 93:42-48, 2011.
24. Petersson LG, Arthursson L, Ostberg C : Caries-inhibiting effects of different modes of Duraphat varnish reapplication: a 3-year radiographic study. *Caries Res*, 25:70-73, 1991.
25. Reynolds EC : Casein phosphopeptide-amorphous calcium phosphate: the scientific evidence. *Adv Dent Res*, 21:25-29, 2009.
26. 박승효, 이상호, 이난영 : 불소 테일 적용 후 시간변화에 따른 타액 내 불소농도. *대한소아치과학회지*, 36:377-386, 2009.
27. Srinivasan N, Kavitha M, Loganathan SC : Comparison of the remineralization potential of CPP-ACP and CPP-ACP with 900 ppm fluoride on eroded human enamel: An in situ study. *Arch Oral Biol*, 55:541-544, 2010.
28. Jayarajan J, Janardhanam P, Jayakumar P : Efficacy of CPP-ACP and CPP-ACPF on enamel remineralization - an in vitro study using scanning electron microscope and DIAGNOdent. *Indian J Dent Res*, 22:77-82, 2011.
29. Castillo JL, Milgrom P, Kharasch E, et al. : Evaluation of fluoride release from commercially available fluoride varnishes. *J Am Dent Assoc*, 132:1389-1392, 2001.

국문초록

불소 테이프의 법랑질 탈회 억제 효과에 관한 실험적 평가

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본 연구의 목적은 법랑질 표면 미세경도의 측정과 주사전자현미경 관찰을 통해 본 교실에서 개발한 2.26%의 불소를 함유한 폴리비닐알코올 테이프 (F-PVA tape)의 법랑질 탈회 억제 효과를 평가하기 위한 것이다.

60개의 법랑질 표본을 각 군당 15개 씩, 임의로 대조군, F-PVA tape 군, 불소바니쉬 군, CPP-ACFP 군으로 나누고, 각각의 재광화 제재를 도포한 후 pH-cycling 과정 거쳤다. 표본의 표면 미세경도를 측정하고 표면 미세경도 소실량을 계산하였다. 주사전자현미경 관찰을 위해, 각 군에서 5개의 표본을 추출하고 형태학적 특징을 분석하였고 다음과 같은 결론을 얻었다.

1. pH-cycling 후, F-PVA tape 군과 불소바니쉬 군의 법랑질 표면 미세경도 값은 CPP-ACFP 군과 비교 시 유의하게 높았으며, F-PVA tape 군과 불소바니쉬 군 사이에는 유의한 차이가 없었다.
2. 주사전자현미경 관찰 시, F-PVA tape 군과 불소바니쉬 군에서는 법랑질 표면에 형성된 수많은 구형 및 난원형의 결정 입자들이 관찰되었으며, 결정 입자의 밀도는 대조군 및 CPP-ACFP 군에서 보다 높았다.

F-PVA tape은 법랑질의 탈회를 억제하는데 효과적이며, 그 효과는 불소바니쉬와 견줄만하고, CPP-ACFP 보다 우수하다.

주요어: 불소 테이프, PVA tape, 법랑질 탈회