

# Fluoride Varnish와 Acidulated Phosphate Fluoride Gel이 인공우식 병소에 미치는 영향에 대한 미세전산화 단층 촬영을 이용한 연구

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## 국문초록

치아 우식의 예방에 있어서 불소 도포는 효과적인 방법으로 재광화를 촉진하고 탈회를 억제한다. APF gel은 전문가 불소 도포용으로 가장 일반적인 방법이었으나 최근 fluoride varnish가 소개되면서 그 사용이 증가되고 있다.

이번 연구의 목적은 fluoride varnish와 acidulated phosphate fluoride(APF) gel이 인공우식 병소에 미치는 영향을 시편의 화학적 고정이나 절단 없이 미세전산화 단층 촬영과 3차원 영상을 이용하여 재광화 효과를 비교해 보고자 함이다.

48개의 우식이 없는 건전한 영구 소구치에 인공우식을 유발하고 각 군당 16개씩, 세 군으로 나누었다. 1군은 대조군으로 어떠한 처치도 시행하지 않았다. 2군은 APF gel을 도포하고 1분 후에 gel을 거즈로 제거하여 수세하고 3군은 fluoride varnish를 도포한 후 45분 후에 얇은 varnish 막을 외과용 칼로 조심스럽게 제거하였다. 그 후 각 시편을 50ml의 인공타액에 3개월 동안 담그어 둔 후 그 사이 기간동안 매달 미세전산화 단층 촬영을 이용하여 3차원 영상을 얻었다. 3차원 영상분석 프로그램으로 재광화 부위의 밀도를 측정하고 다음과 같은 결과를 얻었다.

1. 모든 군에서 시간이 지남에 따라 인공우식 부위의 밀도는 증가하였다.
2. APF gel 군과 fluoride varnish 군에서 한 달, 두 달, 세 달 후 밀도가 대조군보다 통계학적으로 유의성 있게 높았다 ( $P<0.05$ ).
3. APF gel 군과 fluoride varnish 군에서 처치전과 처치 한 달 후의 밀도 차이가 대조군보다 통계학적으로 유의성 있게 높았으며 fluoride varnish 군에서 처치 한 달 후와 처치 두달 후의 밀도 차이가 대조군과 APF gel 군보다 유의성 있게 높았다( $P<0.05$ ).
4. Fluoride varnish가 APF gel보다 불소 처치 후 두 달, 세 달 후 재광화 효과가 더 우수하였고 오래 지속되었다.

**주요어** : Fluoride varnish, Acidulated phosphate fluoride gel, 인공우식 병소, 재광화, 미세전산화 단층 촬영

## I. Introduction

The application of fluoride to the tooth surface has been reported to be effective in preventing dental caries. In addition, it is accepted that topical fluo-

rides promote remineralization and impede demineralization of the tooth hard tissues<sup>1,2)</sup>. Topical fluorides are available in several forms, including fluoride-containing dentifrice, topical fluoride gels and foams, rinses, and varnishes<sup>3)</sup>.

The application of an acidulated phosphate fluoride(APF) gel is the most common mode of professional fluoride therapy in the USA<sup>4)</sup>. The caries-preventive efficacy of APF gels has been shown in numerous studies over the last four decades<sup>5-7)</sup>. APF gels have also been used in Europe, but during the

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\* Supported by a grant no 04-2002-060 from the Seoul National University Hospital Research Fund.

last two decades, application of a fluoride varnish has replaced the gel treatments in many countries. After APF gel application, most of the acquired fluoride fails to react with the enamel and is washed away by the saliva<sup>8)</sup>. Varnishes were invented and has been introduced into dental practice in some Europe countries in order to reduce the fluoride loss. The other reason for the wide acceptance of fluoride varnishes especially in Nordic countries is the easy and fast application procedure<sup>4)</sup>.

Fluoride varnishes have also proved clinically effective in most studies although the number of reports is less than that of APF gels<sup>4,9-16)</sup>. However, the anti-caries effect of APF gels and fluoride varnish applications has been compared in few studies.

In earlier studies, the assessment of remineralization was based on the surface microhardness test of the cross-sections<sup>17)</sup> of the enamel, microhardness measurements of the enamel surface<sup>18)</sup>, different microradiography techniques<sup>19)</sup>, iodine absorptiometry<sup>20)</sup>, confocal microscopy<sup>3)</sup> and light scattering<sup>21)</sup>. An X-ray system usually produces two-dimensional shadow images of the complete internal three-dimensional structures. On the other hand, a microcomputed tomography allows the imaging and measuring of complete three-dimensional object structures without the need for sample preparation or chemical fixation<sup>22)</sup>.

The purpose of this *in vitro* study was to compare the remineralization effects of two topical fluoride agents, APF gel and fluoride varnish with microcomputed tomography and a 3D image analyzer without sample preparation and chemical fixation.

## II. Materials and Methods

### Specimen preparation

Forty eight extracted caries-free permanent premolars were selected for this study. The teeth were stored in a small amount of 0.1% thymol solution to prevent dehydration. An acid resistant nail varnish was applied to the entire surfaces of these teeth with the exception of an area of enamel, approximately 1mm×1mm at the buccal surface. Teeth were then suspended in an artificial caries solution(2.2mM Ca<sup>2+</sup>, 2.2mM PO<sub>4</sub><sup>3-</sup>, 50mM acetic acid)<sup>23)</sup> at a pH 4.4, 37°C and constant circulation for three days.

After caries lesions were formed, the specimens including the artificial caries lesions were obtained from each tooth by sectioning with an ISOMET® Low Speed Saw(BUEHLERTM, Lake Bluff, Illinois, USA). The specimen size was approximately 1mm×3mm(buccal surface)×3mm. Subsequently, each specimen was mounted on a polyacrylic resin block using orthodontic resin, exposing the artificial caries lesion. The specimens were then randomly divided(16 specimens/group) into three treatment groups.

- Group 1 : Control group (No fluoride treatment)
- Group 2 : APF gel (60 second taste®, PASCAL, USA)
- Group 3 : Fluoride varnish(Fluor Protector®, Vivadent, Lichtenstein)

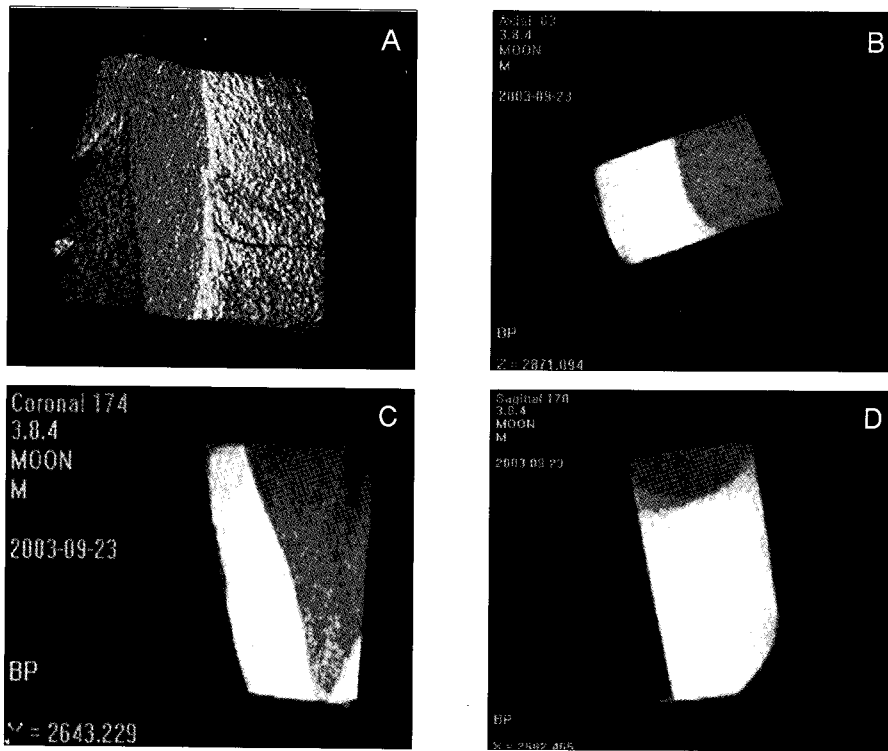
Prior to treatment, an initial 3D image was taken using a desktop X-ray microCT scanner(Skyscan 1072, SkyScan b.v.b.a., Belgium). The operator used 80kV/100µA microfocustube, average cross-section pixel size was 15.190972µm, and the average cross-section distance was 45.572917µm.

#### < Group 1 : Control - No treatment >

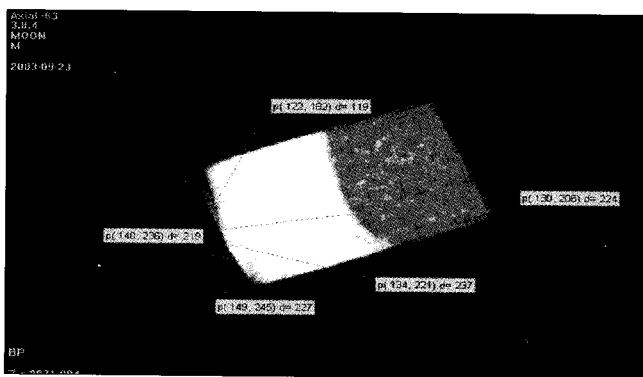
No application was performed on Group 1, which acted as the control group. Each specimen was placed into a closed container with 50mL of an artificial saliva per sample. One hundred ml artificial saliva consisted of 1g Carboxymethyl-cellulose, 84mg NaCl, 120mg KCl, 15mg CaCl<sub>2</sub>, 5mg MgCl<sub>2</sub> and 34mg K<sub>2</sub>HPO<sub>4</sub>. This was maintained at 37°C, pH 7.0, for three months. During that time, 3D images of the remineralization area were taken using SkyScan each month.

#### < Group 2 : APF gel(60 second taste®, PASCAL, USA) >

Each specimen in Group 2 was cleaned with a rubber cup, and treated with an acidulated phosphate fluoride gel(60 second taste®, PASCAL, USA), which was removed with 2×2 gauze after 1 minute. The specimen was then rinsed with deionized water after 30 minutes and placed into the artificial saliva. This was maintained at 37°C, pH 7.0, for three months. In addition, 3D image of the remineralization area of each specimen was taken by using the SkyScan each month during that time.



**Fig. 1.** A: Reconstructed 3D image under V works™ 4.0 (Cybermed, Korea) B: Image slice of Z-axis C: Image slice of Y-axis D: Image slice of X-axis.



**Fig. 2.** The density of the tooth on the remineralization site was measured. The mean of the values measured on the 5 sites in 5 slices was calculated.

< Group 3 : Fluoride varnish(Fluor Protector®, Vivadent, Lichtenstein) >

Each specimen in Group 3 was cleaned with a rubber cup, and dried with a cotton roll and an air syringe. A thin layer of a Fluor Protector® was applied to each specimen using a brush. Each specimen was dried with an air syringe. After 45 minutes, the thin varnish layer was carefully removed with a scalpel. Specimens were then placed into artificial saliva

maintained at 37°C, pH 7.0, for three months, and 3D images of the remineralization area were taken using the SkyScan every month.

#### MicroCT analysis

The 3D images obtained before and after the remineralization period were quantified, and the density of the lesions were compared. Under V works™ 4.0 program (Cybermed, Korea) 3D image reconstructed and 5 image slices of the each specimen were selected(Fig. 1).

The density of the tooth was measured with density-measuring program in V works™(Fig. 2). The mean of the values measured on the 5 sites in the 5 slices was calculated.

The characteristics of the measured sites were as follows:

the area of the dot : 30,000~500,000 $\mu\text{m}^2$

the range of the diameter of the dot : 200~250 $\mu\text{m}$

the measured site : the middle of the artificial caries lesion or the remineralization area

Statistics

One-way ANOVA, and Scheffe's multiple comparisons procedure were used to statistically analyze the groups. A P value < 0.05 was considered significant.

III. Results

Fig. 3 showed the reconstructed 3D images as a function of time and Table 1 showed the mean(± S.D.) density values of the specimen during three months. All groups demonstrated an increase in density of artificial caries lesion. This indicated that the

artificial caries lesion was remineralized. ANOVA indicated significant variance in the mean density, when comparing the experimental groups(p<0.05). Scheffe's test demonstrated that no statistically significant difference was found in all group before treatment. However, the density was significantly higher in APF gel group and fluoride varnish group than the control group at 1 month, 2 months, and 3 months after treatment. Moreover, the density of the fluoride varnish group was significantly higher than that of the APF gel group at 2 and 3 months after treatment. At 1 month, the density of the fluoride

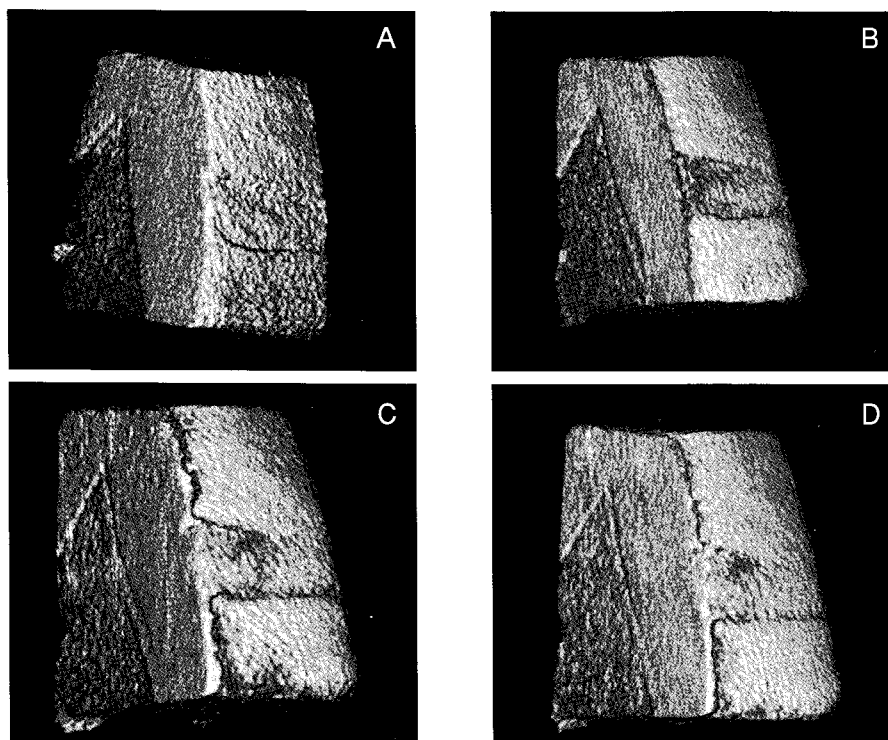


Fig. 3. Reconstructive 3D image of enamel caries lesion in remineralizing A: before the fluoride varnish treatment B: One month after the fluoride varnish treatment C: Two months after the fluoride varnish treatment D: Three months after the fluoride varnish treatment.

Table 1. The mean density of each group according to the duration of remineralization

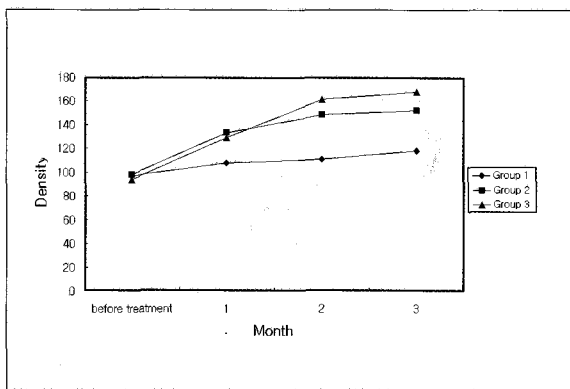
Group	before treatment	1 month after treatment	2 months after treatment	3 months after treatment
1	96.54±21.79	107.46±16.09	111.00±15.39	118.00±17.55
2	97.96±17.53	133.19±18.40	148.27±14.01	152.07±15.61
3	95.98±18.14	123.27±20.95	161.27±13.39	167.64±15.13
Groups significantly different*		1 vs. 2 : P<0.05 1 vs. 3 : P<0.05	1 vs. 2 : P<0.05 1 vs. 3 : P<0.05 2 vs. 3 : P<0.05	1 vs. 2 : P<0.05 1 vs. 3 : P<0.05 2 vs. 3 : P<0.05

**Table 2.** Difference in density within groups (P value)

Group	before treatment	1 month	2 months	before treatment vs. 3 months : P = 0.014
	vs. 1 month	vs. 2 months	vs. 3 months	
1	0.402	0.957	0.747	
2	0.001	0.093	0.935	
3	0.001	0.001	0.734	

**Table 3.** The mean  $\Delta D$ (difference of density) between 1 month in one specimen

Group	$\Delta D1$	$\Delta D2$	$\Delta D3$
1	12.06±9.56	3.23±5.40	6.65±9.54
2	35.23±16.32	15.08±15.27	3.86±11.57
3	35.74±16.46	31.54±22.44	6.94±15.88
Groups significantly different*	1 vs. 2 : P<0.05 1 vs. 3 : P<0.05	1 vs. 3 : P<0.05 2 vs. 3 : P<0.05	



**Fig. 4.** The change of the density in three groups.

varnish group was lower than that of the APF gel group, but the difference was not statistically significant.

When comparing the density within the groups, there was no statistically significant difference with time in the control group. However, ANOVA indicated that the density 3 month after treatment was significantly higher than that before treatment ( $p < 0.05$ ) (Table 2). When compared with the density before treatment in the APF gel group, the density 1 month after treatment was significantly higher, but the difference was not statistically significant. In the fluoride varnish group, the density at 1 and 2 months

was significantly higher than the density prior to treatment ( $P = 0.001$ ).

$\Delta D$  was calculated in order to reduce the statistical error.  $\Delta D$  was the difference in the density between before and after treatment in a single specimen.  $\Delta D1$  was the difference in the density between that "prior to treatment" and that "1 month after treatment".  $\Delta D2$  is therefore the difference in the density between that "1 month after treatment" and that "2 months after treatment", and  $\Delta D3$  was calculated in the same way. Table 3 depicts the mean  $\Delta D$  values of the three experimental groups.  $\Delta D1$  of Group 2 and Group 3 was significantly higher than that of Group 1 and  $\Delta D2$  of group 3 was significantly higher than those of Group 1 and 2. However, the difference in the three groups regarding  $\Delta D3$  was not statistically significant.

#### IV. Discussion

APF was first introduced by Brudevold et al.<sup>24)</sup> in 1963. The semiannual topical application of the acidulated phosphate fluoride (APF) gels containing 1.23% fluoride has been shown to be an effective method of reducing the incidence of dental caries in test populations of children<sup>5-7)</sup>. The use of these agent, particularly as gels, has become popular

among dental practitioners. The gel types are convenient to apply and appear to be as effective as the solutions<sup>5)</sup>.

Most of the APF gels available today employ a cellulose base to achieve the desired viscosity. Recently, some gel products have been introduced which have been described as "thixotropic". This term refers to substances that increase their flow under pressure and return to their viscosity when the pressure is released. The manufacturers claim that these characteristics make the agents more convenient to use and is possibly more effective<sup>5)</sup>.

Although clinically effective, the use of APF gels in the recommended manner has some drawbacks. The bitter taste resulting from the low pH(3.2~3.5) might not be well disguised and some children may find a one- or four-minute application an unpleasant experience. Several factors can lead to the over-ingestion of the gel, followed by nausea and vomiting. These factors include excess gel in the trays, the use of ill-fitting trays, a failure to lean the patient's head forward, the improper placement of an intra-oral suction during the application, the failure to suction and expectorate gel remaining in the mouth after the trays are removed. Carelessness during application may result in elevated fluoride plasma levels that can have a transient effect on the liver and renal function<sup>25)</sup>.

Schmidt introduced the first fluoride varnish in 1964, under the trade name Duraphat®(Woelm Pharma Co., Eshwege, Germany)<sup>26)</sup>. Duraphat® is a natural resin, a neutral colophonium base, containing 5% wt NaF (2.26% F<sup>-</sup>) dissolved in ethanol. The Duraphat® varnish that sets on the tooth surface is a yellow-brown film and is banana flavored. Arends and Schuthof<sup>27)</sup> introduced a second product in 1975 under the trade name Fluor Protector®(Vivadent, Schaan, Lichtenstein). This is a polyurethane-based transparent resin, containing 0.1% F<sup>-</sup> as difluorsilane(0.9% wt) dissolved in an ethyl acetate and isoamylpropionate solution. The other ingredients are sodium saccharin(used as a sweetener), a flavor, and beeswax(forms a gel type structure)<sup>28)</sup>. The different dissolving agents used in the two lacquers greatly influence not only the adhesive properties, but also the bioavailability of fluoride ions. The lower concentration of fluoride in Fluor Protector potentially poses an even lower risk of the over-ingestion of fluoride,

although there is no clinically significant risk from the use of any of the varnish products. The acidic properties of Fluor Protector® like those of the APF gel, increase the fluoride uptake of the enamel<sup>29)</sup>.

Recently, other fluoride varnishes have been discussed in literature. Nevertheless, their diffusion through the European market is not comparable to that of Duraphat® and Fluor Protector®.

Fluoride varnishes have important favorable clinical features. They are quick and easy to apply, and the patient's acceptance is good. Often it can be applied to young children, handicapped patients, and otherwise difficult patients for whom a conventional gel application cannot be accomplished. Perhaps of most importance is that the amount of fluoride ingested is small. In the resin varnishes, the fluoride concentration, 22,000ppm<sup>28)</sup>, is approximately twice as high as in the APF gel, but the amount of fluoride in the mouth of a child as a result of the application of a varnish is <7mg compared to the 30mg with an APF application<sup>25)</sup>. This is because the varnish sets rapidly and the saliva promotes the setting of varnish, and only small doses are required<sup>28)</sup>. In the case of the APF gel, very careful application of gel can reduce the amount of fluoride ingested to approximately 10mg<sup>30)</sup>. However, it is difficult to achieve this low level of ingestion, particularly in young children. The dose from a gel application is swallowed in a short period of time and can cause significant increases in the plasma fluoride concentration. In contrast, in a varnish application, a much smaller dose is swallowed over a number of hours, so the possibility of nausea, vomiting, or other fluoride toxic reaction is eliminated. Fluoride ingestion following a varnish application has barely detectable effects on the plasma fluoride concentration<sup>31)</sup>. Ekstrand and Koch<sup>32)</sup> investigated the plasma fluoride concentration after a single application of 5 ml of a 1.23 percent fluoride gel. For 30 minutes, the plasma fluoride level was 50 times higher than that prior to the application, which then decreased comparatively rapidly during the next four hours and more slowly thereafter. However, for 14 hours the concentration was 10 times higher than the baseline level. They also investigated the plasma fluoride concentration following the application of Duraphat®<sup>31)</sup>. They reported that the plasma fluoride level was the highest after 2 hours, which then decreased. After 2 hours, the con-

centration was 5~6 times higher than that in the stable state, but the plasma levels was far below those considered toxic. This reports showed that the fluoride varnish was safer than the APF gels, although the plasma fluoride level of the fluoride varnish and APF gels was far below the toxic dose.

In short, a fluoride varnish is at least as effective as the APF gel and is free of the important disadvantages of gel applications. The only disadvantage was the dull appearance of the teeth for the first few hours after applying the varnish and the side effect of the contact allergy to Duraphat, which was first reported by Isaksson et al.<sup>33)</sup>

In this study, all the groups demonstrated a increase in the density of the artificial caries lesion with time. However, the density was significantly higher in the APF gel group(Group 2) and the fluoride varnish group(Group 3) than in the control group(Group 1) at 1 month, 2 months, and 3 months after treatment. This indicates that the APF gels and fluoride varnishes are effective methods for remineralizing incipient caries. Moreover, the fluoride varnish was more effective than the APF gel. Although the effect of the fluoride varnish and APF gel was similar for a month, the remineralization of the fluoride varnish was significantly greater than that of the APF gel. This means that the effect of the fluoride varnish was more effective and more continuous.

The  $\Delta D$  was calculated in this study in order to reduce the statistical error.  $\Delta D1$  of Group 2 and Group 3 were significantly higher than that of Group 1, and  $\Delta D2$  of Group 3 was significantly higher than that of Group 1 and Group 2. However, no statistically significant difference in the three groups was found in  $\Delta D3$ . As previously stated, this indicates that the remineralization of the artificial caries in the fluoride varnish group and the APF gel group was much higher for a month, but the density of only the fluoride varnish group was significantly increased at two months. No statistically significant difference in the three groups was found in  $\Delta D3$ . The remineralization effect of the APF gel and fluoride varnish was not continuous for three months after treatment. Therefore, in order to produce continuous remineralization, it may be necessary to re-apply the fluoride agents after three months.

Perhaps the most interesting result was observed

in the control group. In the control group, the specimens were not treated with fluoride. However, the density of most of the artificial lesions increased. Presumably this increase was the result of the deposition of calcium salts from the artificial salivary solution into the parts of the lesion that had been most recently demineralized<sup>34)</sup>.

Numerous studies have shown fluoride varnishes to be clinically effective<sup>4,9-16)</sup>. Holm<sup>10)</sup> evaluated semiannual applications of a fluoride varnish in 3-year-old children and found a 44 percent reduction in caries after two years. Peyron et al.<sup>11)</sup> studied the progression of approximal caries in the primary dentition and the effect of the varnish on caries progression in 3- to 6-year-old children. After one year, 51.2 percent of the enamel lesions in the varnish group exhibited progression, which contrasts with the 82.8 percent progression of the lesions in the control group. These authors concluded that the semiannual application of a varnish had a cariostatic effect. Twetman and Petersson<sup>12)</sup> studied the effect of fluoride varnish on caries incidence in 4- to 5-year-old children, using the WHO criteria and observed that the fluoride-silane varnish had a cariostatic effect in the primary dentition. Frostell et al.<sup>16)</sup> studied the effect of semiannual applications of varnish on the development of caries in the primary dentition of a 4-year-old children and found a 30 percent reduction in the incidence of caries. The mean caries increment was 2.86 dmfs in children in the varnish group and 4.10 dmfs in the children in the control group. When the initial caries lesions were included in the dmfs index, the difference between the groups was also significant.

Janna et al.<sup>9)</sup> studied the effect of a fluoride varnish on the progression of enamel caries in the primary dentition. They indicated that application of fluoride varnish two times may be effective in arresting the early active enamel lesions in the primary dentition. Zimmer et al.<sup>13)</sup> studied the effect of a fluoride varnish in a community with a low socioeconomic status and a generally high caries level. Children who received a minimum of applications of fluoride varnish twice per year for two years exhibited a significantly low increment of caries when compared to children in the control group.

There have been many studies on the remineralization effect in the APF gels and fluoride varnishes,

but there are few reports comparing the remineralization effect of the APF gels and fluoride varnish. A recent meta-analysis of eight clinical trials indicated that fluoride varnish is at least as effective, if not more so, than the APF gels. An individual review of other relevant publications supports this conclusion. Clark et al.<sup>35)</sup> compared the empirically based-effectiveness of caries preventive agents. They estimated that fluoride varnish treatments are more effective than APF solutions and gels. Seppä et al.<sup>4)</sup> compared the caries preventive effect of a sodium fluoride varnish and an APF gel. A total of 254 children aged 12-13 years with a past caries experience were randomly divided into two groups. The participants received semi-annual applications of either fluoride varnish or gel. During the study, the mean( $\pm$ SD) total DMFS increments of the varnish and gel groups were  $6.8\pm 5.6$  and  $7.7\pm 6.4$ , respectively, when the initial caries was included, and  $3.1\pm 3.7$  and  $3.6\pm 4.6$  when the initial caries was excluded. This difference was not statistically significant. The results suggest that the fluoride varnish is as effective as fluoride gel at least in preventive approximal caries.

Retief et al.<sup>36)</sup> studied the *in vitro* fluoride acquisition by human enamel after 1-hour and 24-hour application of APF, Duraphat, or Fluor Protector. They reported that acquisition of fluoride was the greatest in the teeth treated with the Fluor Protector and the least in the APF-treated teeth. Kim et al.<sup>37)</sup> compared the effect of the fluoride varnish and the APF gel on the artificial caries lesion with a microhardness test. They reported that the fluoride varnish was as effective as the APF gel *in vitro* study. This *in vitro* remineralization study using microcomputed tomography also supports these conclusions.

The method described in this investigation was a new and objective way for assessing the remineralization on the artificial caries lesion. An X-ray system usually produces two-dimensional shadow images of the complete internal three dimensional structures. However, the depth information is completely mixed in a single two-dimensional shadow projection. Only an X-ray tomograph system allows the imaging and measurement of complete three-dimensional object structures without sample preparation or chemical fixation. Typically the spatial resolution of conventional medical CT-scanner ranges from 1 to 2.5mm, which corresponds to a 1 to 10 cu-

bic mm voxel (volume element) size. The system "SkyScan 1072" allows a spatial resolution of  $10\mu\text{m}$ , which corresponds to an almost  $1\times 10^{-6}$  cubic mm voxel size. The hardware device used in this study was a SkyScan 1072, which provided the data sets that were used for qualitative and quantitative purposes. The system consists of a combination of an X-ray shadow microscopic system and a computer with tomographic reconstruction software. This system allows for the non-destructive three-dimensional reconstruction of an object's inner structure from the two-dimensional X-ray shadow projections. The equipment contains an X-ray microfocus sealed X-ray tube with a high-voltage power supply, a  $10\sim 40\mu\text{m}$  spot size, a specimen stage with a precision manipulator, a two-dimensional X-ray CCD camera ( $512\times 512$  pixels) connected to the frame-grabber and a Dual Pentium computer with a color monitor.

The V works™ program used for analyzing 3D images is a PC-based program used to reconstruct a medical image from CT, MRI, and 3D Ultrasonography into various image formats. It can also create, save, and manage 3D medical models as well as other images according to the clinical demands. In this study, the major use was to create 3D images of the tooth specimens and to measure the density values of the image slices.

The advantages of this method are as follows: first, microcomputed tomography is non-destructive, as opposed to a microbiologic study. Second, because the specimen preparation process is omitted, the operator can freely choose and change any portion of the specimen to be analyzed. Third, comparison can be made before and after on a specific portion of the specimen. This ability allows a more accurate analysis of the specimen than a random selection of a slice or a specimen dissection, which gives only one comparison per specimen. Fourth, an analysis of the long-term changes in a single specimen is possible because there is no need for the specimen preparation.

In this study, the authors compared the remineralization effect of the APF gel and fluoride varnish with microcomputed tomography and a 3D image analyzer. This *in vitro* study indicated that the fluoride varnish was more effective than the APF gel in the remineralization of the artificial caries lesions. However, further studies will be needed to determine



the remineralization effects of the fluoride varnish and to develop more effective and safer fluoride agents.

## V. Conclusions

An artificial caries lesion was caused on a caries-free permanent premolar and 48 specimens were divided into three groups each containing 16 specimens. No application was performed on group 1, which acted as the control group. Group 2 was treated with the APF gel and was removed after a minute. Group 3 was treated with the topical application of a fluoride varnish and was removed after 45 minutes. Each specimen was placed into a closed container with 50ml of artificial saliva during three months and the 3D images of the remineralization area were taken using microcomputed tomography each month. Using the density-measuring program in the 3D image analyzer, the density value of the remineralization area was measured. The following results were obtained:

1. All the groups demonstrated an increase in the density of the artificial caries lesion with time.
2. The density was significantly higher in the APF gel and fluoride varnish group than in the control group at 1 month, 2 months, 3 months after treatment( $P<0.05$ ).
3. The difference of the density between that "prior to treatment" and that "1 month after treatment" in Group 2 and Group 3 was significantly higher than that of Group 1 and, the difference of the density between that "1 month after treatment" and that "2 month after treatment" in Group 3 was significantly higher than that of Group 1 and 2( $P<0.05$ ).
4. The fluoride varnish was more effective after 2 and 3 months and continuous than the APF gel.

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Abstract

THE EFFECT OF FLUORIDE VARNISH AND ACIDULATED PHOSPHATE FLUORIDE GEL  
ON ARTIFICIAL CARIES LESION  
- A MICROCOMPUTED TOMOGRAPHIC STUDY -

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The application of acidulated phosphate fluoride gel (APF) and fluoride varnishes are the most common topical fluoride therapy. The purpose of this in vitro study was to compare the remineralization effects of two topical fluoride agents, APF gel and fluoride varnish with microtomograph and 3D image analyzer without sample preparation and chemical fixation.

For the purpose of the study, the artificial caries lesion was caused on the caries-free permanent premolar and 48 specimens were divided into three groups each containing 16 specimens. No application was performed on group 1, which acted as control group. Group 2 was treated with APF gel and was removed after a minute. Group 3 was treated with the topical application of fluoride varnish and removed after 45 minutes. Each specimen was placed into a closed container with 50ml of a artificial saliva during three months and the 3D images of the remineralization area were taken using the SkyScan each month. Using the density-measuring program in V works™, the density value of the remineralization area was measured.

The following results were obtained:

1. All groups demonstrated an increase in the density of artificial caries lesion with time.
2. The density was significantly higher in APF gel and fluoride varnish group than control group at 1 month, 2 months, 3 months after the treatment ( $P < 0.05$ ).
3. The difference of the density between that "prior to treatment" and that "1 month after treatment" in Group 2 and Group 3 was significantly higher than that of Group 1 and, the difference of the density between that "1 month after treatment" and that "2 month after treatment" in Group 3 was significantly higher than that of Group 1 and 2 ( $P < 0.05$ ).
4. The fluoride varnish was more effective after 2 and 3 months and continuous than the APF gel.

**Key words** : Fluoride varnish, Acidulated phosphate fluoride gel, Artificial caries lesion, Remineralization, Microcomputed tomography