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What is This?
Effectsof Two Fluoride Gels on Fluoride Uptake and Phosphorus Loss During Artificial Caries Formation

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Blocks of human enamel were cycled through a demineralization - F-treatment-remineralization procedure and then analyzed for fluoride and the presence of caries-like lesions. Treatments with a sodium fluoride gel (5000 ppm F) increased the enamel fluoride concentration to 6500 ppm F, whereas a stannous fluoride gel (1000 ppm F) increased enamel fluoride to about 1200 ppm F. Although a control treatment (water) allowed caries-like lesions to form, as observed by microradiography, no lesions were found in either of the fluoride-treated groups. When the experiment was repeated with radioactive teeth, mineral loss, as determined by release of 32P, was again greatest in the water-treated control group, but some loss was observed in the fluoride treatment groups. The least loss was found in the sodium fluoride group.

It was concluded that the fluoride treatments not only increased enamel resistance but also enhanced remineralization so that calcium phosphate was replaced during the subsequent remineralization phase. Because of the probability that stannous ions were deposited during the stannous fluoride treatment, some of the apparent calcium phosphate re-deposition in this group was probably stannous compounds.


Introduction.

Frequent self-applications of sodium fluoride gels to the dentition by mouthtrays have been shown to be a very effective means of preventing dental caries formation (Englander et al., 1967; 1969; 1971). Stannous fluoride in aqueous solution has also been used for topical application, and until recently it was widely used in a dentifrice (Mellberg and Ripa, 1983). Stannous fluoride solutions for topical application usually contain 20,000 ppm F and dentifrices 1000 ppm F. Sodium fluoride and stannous fluoride gels are currently available for topical application to the teeth either by mouthtray or toothbrush. The sodium fluoride product contains 5000 ppm F at neutral pH, similar to the gel tested in previous clinical trials (Englander et al., 1967; 1969; 1971), and the stannous fluoride products contain 1000 ppm F at acid pH in anhydroxylic glycerine vehicle (for retention of stannous ion activity).

Because these products differ significantly in fluoride concentration, pH, and vehicle, it was of interest to determine how they performed in inhibiting the formation of artificial caries lesions in an in vitro system that included demineralization, treatment, and remineralization phases. Two experiments were conducted. The first determined fluoride uptake and evaluated mineral loss by microradiography, and the second determined mineral loss by measuring radioisotopic release from the previously irradiated teeth.

Materials and methods.

Experiment 1. — Sixty blocks of human enamel approximately 3 × 5 mm were cleaned with pumice and mounted on plastic sticks exposing only the intact outer surfaces. They were given an artificial caries challenge by immersion into a pH 4.6, 0.1 mol/L lactic acid solution containing 500 mg dissolved hydroxyapatite for 16 hrs at 37°C. After being rinsed for one min in distilled water, they were randomly assigned to one of three groups. One group was treated with a 1:1 aqueous dilution of a sodium fluoride gel (Prevident Brush-on Gel, Colgate-Hoyt, Norwood, MA) at 37°C, another group was similarly treated with a stannous fluoride gel (Gel-Kam, Scherer Laboratories, Dallas, TX), and the third group was treated with distilled water.

After residual gel was rinsed from the blocks for one min with distilled water, they were placed in an artificial saliva solution for eight hours at 37°C, to allow remineralization to occur. The artificial saliva contained, in mmol/L, 1.5 KH2PO4, 2.0 CaCl2, 2.5 urea, 8.3 NaHCO3, 4.8 NaCl, and 137 KCl, and had a pH of 7.1. This sequence of caries challenge, fluoride treatment, and remineralization was repeated five times (Mallon and Mellberg, 1984). After the five sequences, ten blocks from each group were analyzed for fluoride, and the remaining blocks were analyzed for lesion formation (Mallon and Mellberg, 1985). The latter was done using thin sections cut from the blocks, after being embedded in epoxy, which were polished to 100-μm thickness. The polished sections were radiographed on fine-grain film, and density measurements of the lesion areas on the radiographs were made with a scanning microdensitometer. Each scan was automatically converted to percent mineral data by a computer and plotted for analysis. The scans were corrected for the non-linearity of the film, by means of a series of aluminum and enamel standards.

Enamel was analyzed for fluoride by a standard method (Nicholson et al., 1974). Briefly, ten layers were individually removed by immersion for one min in 0.5 mol/L HClO4. Each layer was analyzed for F⁻ by specific ion electrode and for Ca²⁺ by atomic absorption spectrophotometry. Fluoride concentrations were calculated under the assumption that enamel contains 36% calcium and has a density of 2.96 g/ml.

Experiment 2. — Thirty blocks of sound human enamel approximately 5 mm × 5 mm were cleaned with pumice as in experiment 1 and irradiated at the University of Missouri reactor facility at a flux density of 1.2 × 1012 neutrons/sq cm/sec, following the procedure used by the American Dental Association for dentifrice abrasivity evaluation (Heffernan, 1976). After irradiation, they were allowed to stand in water for several days to allow for decay of all short-lived isotopes, leaving 32P as the only major radioisotope present. The irradiated blocks were then mounted on plastic sticks and treated according to the cyclic demineralization-treatment-remineralization procedure used in experiment 1. Each of these solutions was analyzed for radioisotopic by dispersion of a 1-mL aliquot in 10 mL Aquasol II liquid scintillation cocktail (New England Nuclear, Boston, MA) and counting for one minute in a Beckman LS-6800 liquid scintillation counter. All counts were compensated mathematically for decay during the time of the experiment.

To evaluate the phosphorus data, we divided each count...
from a demineralization solution by the count found for the same tooth from the initial demineralization. This normalization eliminated scatter of data due to tooth-to-tooth variation.

Results.

Experiment 1. — The fluoride uptake profiles from the three treatment groups in experiment 1 are shown in Fig. 1. The sodium fluoride gel increased enamel fluoride to 6500 ppm F in the outer layer of the enamel, whereas the stannous fluoride gel resulted in a maximum level of 1200 ppm F. The placebo group contained about 800 ppm F in the outer layer. The difference between sodium fluoride and stannous fluoride treatments persisted until the fifth layer. Based on previous experiments, this corresponds to a depth in the range of approximately 50 to 75 μm (Mallon and Mellberg, 1985).

The average microdensitometric scans for the groups in experiment 1 are shown in Fig. 2. The water-treated control group had a typical artificial white-spot profile. The surface layer was demineralized 22% and the body of the lesion 30%. The density scan of the average lesion indicates that the depth was approximately 70 μm. Sodium fluoride and stannous fluoride both apparently protected the enamel from lesion formation.

Experiment 2. — The mean amounts of radiophosphorus found in the initial demineralizing solutions for the water, sodium fluoride, and stannous fluoride treatments were 3116 ± 1188, 2527 ± 913, and 2368 ± 1088 cpm, respectively. A small amount of radiophosphorus, approximately 2-5% of that found in the initial demineralization solution, was found in the water or subsequent fluoride treatment solutions. This was near the background level of the counter.

The relative amounts of radiophosphorus found in each of the remineralizing and demineralizing solutions are listed in Table 1, and a graphic presentation of the total radiophosphorus lost within each cycle is given in Fig. 3. The differences between the water treatments and the two fluoride treatments within each cycle are significant at p<0.001. The sodium fluoride gel was significantly better in inhibiting radiophosphorus loss than was stannous fluoride at p<0.001 (cycle 1), p<0.01 (cycle 2), and p<0.001 (cycles 3 and 4).

Sodium fluoride and stannous fluoride became increasingly effective as more treatments were given. The first treatment reduced the amount of radiophosphorus found in the subsequent remineralizing plus demineralizing solution 37.6% and 25.6% for sodium fluoride and stannous fluoride, respectively (Table) (e.g., [1-(0.260+0.364)]×100 = 37.6%). These values increased to 69.8% and 54.4%, respectively, in the final cycle. Correlation coefficients relating relative radiophosphorus in the remineralizing plus demineralizing solutions to cycle were −0.95 and −0.88 for sodium fluoride and stannous fluoride, respectively. There was no significant trend showing a change in radiophosphorus loss in the water group (r = 0.195).

Discussion.

It is widely assumed that intra-oral enamel undergoes both demineralization and remineralization phases, and it is only when there is more demineralization than remineralization that a lesion develops. The present experiment includes both phases and shows the effects of two fluoride agents.

The finding that a significantly greater amount of fluoride was deposited in enamel treated with sodium fluoride than in enamel treated with stannous fluoride is not surprising in view of the five-fold-higher concentration in the sodium fluoride gel. Furthermore, the stannous fluoride gel is based on anhydrous glycerine, a solvent that has been shown to reduce fluoride reactivity (Ericsson, 1961). It can be hypothesized that the higher enamel fluoride reservoir provided by the sodium fluoride gel will better protect the lesions from subsequent caries challenges. The evidence showing reduced mineral loss in experiment 2 supports this possibility.

The microdensitometric scans of radiographs of enamel treated with water in experiment 1 showed that the cyclic system formed caries-like lesions. They also indicated that sodium fluoride and stannous fluoride treatments were totally effective in preventing lesion formation. Contrary to the data shown in Fig. 2, the results with radioactive enamel indicate that some mineral loss or lesion formation occurred even after treatment with the fluoride gels. As expected, the greatest loss was in the demineralizing solutions. The significant amount of radiophosphorus found in the remineralizing solutions probably arose from diffusion of previously dissolved mineral from the enamel and into the remineralizing solution. The very small amount of radiophosphorus found in the treatment solutions probably
also arose from this source, but since the treatment (diffusion) time was short, only a small amount was found.

Another possible reason why relatively large amounts of radiophosphorus were found in remineralizing solutions is that iso-ionic exchange of radiophosphorus with natural phosphorus ($^{31}$P) occurred. If it is assumed that the amount of exchange was similar for each group, the presence of iso-ionic exchange would tend to decrease the percentage difference between the two fluoride gels, but would not change the finding of a difference between the two agents.

By considering the findings of both experiments, we can conclude that demineralization did occur in all groups but less in the sodium fluoride group. However, remineralization was sufficiently enhanced by the fluoride treatments to replace all or most of the lost mineral. Whether all of the mineral was actually replaced cannot be determined by these experiments, since the microdensitography had an inherent error of approximately 2-3%, and the effect of stannous ion deposition is unknown.

If all calcium phosphate mineral had been replaced in both sodium fluoride and stannous fluoride groups, and if, in addition, some stannous ion deposition took place in the stannous fluoride group, a hypermineralized surface layer might have been observed in the radiographs of the latter. This is because the radiopacity of the stannous atoms must be added to that of the calcium phosphate. Uptake of stannous salts by enamel, causing the masking of early lesions, has been reported (Lobene et al., 1966; Glass, 1967), and it has been stated that the presence of more than 1000 ppm Sn will significantly increase the radiopacity of radiographs (Hals and Selvig, 1977). Since hypermineralized surface layers were not found and it is likely that more than 1000 ppm Sn would have been deposited during the four treatments, the effect of radiopacity from this source cannot be ignored and suggests that not all of the calcium phosphate lost during demineralization was replaced after the stannous fluoride treatments. This agrees with the findings of greater fluoride uptake and lower mineral loss in the sodium fluoride groups.

The present experiments point out the value of radioactive enamel in the study of demineralization and remineralization mechanisms and demonstrate the existence of the demineralization-remineralization equilibrium. It should be possible, therefore, to determine separately, at least semi-quantitatively, the amount of mineral loss and gain during these two phases of the equilibrium.

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REFERENCES


Fig. 3—Relative total radiophosphorus loss in demineralization and remineralization solutions within each cycle. Error bars are standard deviations.