

## Fluoride uptake into demineralized primary enamel from fluoride-impregnated dental floss in vitro

Johnna Jørgensen, DDS Mansour Shariati, DDS, MS  
Carol P. Shields, MS David P. Durr, DMD, MS  
Howard M. Proskin, PhD

### Abstract

*Fluoridated mouthrinses are not advised for preschool children who may swallow much of the agent. An alternate method of delivering topical fluoride to the interproximal tooth surfaces in these young patients may be fluoridated dental floss. The purpose of this study was to determine the fluoride levels of demineralized primary enamel both before and after the use of a commercially available dental floss impregnated with commercially available fluoride-containing products. The results showed that demineralized primary tooth surfaces treated with fluoride-impregnated dental floss exhibited significantly higher fluoride levels than those surfaces treated by immersion in a fluoridated mouthrinse or deionized water.*

Frequent application of relatively low concentrations of fluoride appears to be the most effective means of preventing caries (Ericsson and Forsman 1969; Ripa et al. 1980; Featherstone et al. 1986). The continual presence of low fluoride concentrations appears to effectively inhibit demineralization even in highly caries-susceptible patients. Featherstone et al. (1986) found that a sodium fluoride (NaF) dentifrice with 1100 ppm F used daily in combination with a 0.05% NaF mouthrinse gave complete protection against demineralization in orthodontic patients. However, such a regime may not be advised for children younger than 5 or 6 years of age who may swallow rather than expectorate much of the fluoride mouthrinse (Ericsson and Forsman 1969; Ripa et al. 1980; McDonald and Avery 1983).

An alternate method of fluoride delivery for prevention or remineralization of interproximal lesions in preschool children may be fluoridated dental floss. Fluoridated floss is not a new concept. However, previous studies (Chaet and Wei 1977; Bohrer et al. 1983) did not use products that were commercially available in this country. The purpose of this study was

to determine the fluoride uptake of demineralized human primary enamel following the use of commercially available dental floss impregnated with fluoride-containing products.

### Materials and Methods

A preliminary study was conducted to determine if soft filament floss (Super-Floss® — Oral-B Laboratories; Redwood City, CA) would be impregnated with fluoride following immersion in fluoride-containing products. Thirty-six pre-cut strands (weight  $0.59 \pm 0.002$  g) were divided into 3 groups. Each was immersed into one of the following for 5 min: 0.05% NaF mouthrinse (225 ppmF; ACT Fluoride Dental Rinse® — Johnson & Johnson; New Brunswick, NJ); 1:3 slurry of fluoridated dentifrice (1100 ppmF as NaF; Crest® — Procter and Gamble, Cincinnati, OH) with double deionized water (DDW) (275 ppmF); or double deionized water (DDW).

The fluoride content in each impregnated strand was assayed via the analytical procedure described by Taves (1968), and mean fluoride levels were calculated for each group. The results are shown in Table 1. These data clearly demonstrated that the soft filament floss absorbed fluoride from both the mouthrinse and the toothpaste slurry.

Following the preliminary study, 40 extracted human primary molars free of interproximal lesions

TABLE 1. Fluoride Absorption by Soft Filament Floss

Impregnating Agent	N	ugF/g Floss
NaF mouthrinse (225 ppm F)	12	201 ( 19) <sup>a</sup>
F dentifrice slurry (275 ppm F)	12	248 ( 17)
DDW (control)	12	0.2 (.03)

<sup>a</sup> Mean (standard error)

were cleansed thoroughly with a 10% liquid soap (Liquid Ivory Soap® — Procter and Gamble; Cincinnati, OH) solution, rinsed with DDW, and air dried. Each sample was coated with acid-resistant nail varnish with the exception of small (approximately 3 x 5 mm), rectangular windows located below the contact points on the mesial and distal surfaces. The 40 teeth were divided into 8 groups of 5 teeth each. The teeth in each group were aligned such that interproximal surfaces were in contact, and the roots were then embedded in acrylic blocks. The acrylic in the 8 blocks was also coated with nail varnish.

The 8 blocks were divided into 2 sets. Deep artificial lesions were created in the first set by immersing each acrylic block for 96 hr at 25° C in 200 mL of a demineralizing solution containing 0.075 mol/L acetate and 2.0 mmol/L calcium phosphate (CaHPO<sub>4</sub>) at pH 4.3. Shallower lesions were created in the second set by immersing each acrylic block for 108 hr at 25° C in 200 mL of a demineralizing solution containing 0.1 mol/L acetate, 1 mmol/L CaHPO<sub>4</sub>, 0.1 ppm F at pH 5.0 (Featherstone et al. 1983).

After creating the artificial lesions, the blocks were removed from the demineralizing solutions and the teeth in each block were carefully separated from one another with a separating disk. One-half of each unvarnished rectangular window was sampled for fluoride using the perchloric acid-etch enamel biopsy technique described by Weatherell and Hargreaves (1965). The fluoride in each biopsy was analyzed using a fluoride combination electrode (Orion 96-09 — Orion Research Inc; Cambridge, MA) attached to an ion analyzer (Beckman-Altex 71 — Beckman Instruments Inc; Fullerton, CA). In addition, calcium was analyzed by atomic absorption, after dilution with 1000 ppm potassium chloride, using a nitrous oxide/acetylene burner and a spectrophotometer (Perkin-Elmer 403 — Perkin-Elmer; Norwalk, CT). Assuming calcium to be 37% of etched enamel mineral, the total amount of etched enamel was determined for each sample. Then, the fluoride content of each sample was related to the total amount of etched enamel to determine the fluoride concentration (µgF/g enamel).

After determining the fluoride concentration of the artificial lesions, the biopsy sites were varnished and the teeth were rearranged in their respective order so that the artificial lesions were facing one another below the contact points. The tooth roots were reembedded in acrylic blocks, and the acrylic was varnished again.

The deep and shallow samples were divided into 4 treatment groups with each receiving one of the following 60- to 90-second treatments twice daily for 7 days:

- Interproximal cleaning with floss impregnated with

0.05% NaF mouthrinse (225 ppm F)

- Interproximal cleaning with floss impregnated with a 1:3 slurry of fluoridated dentifrice with DDW (275 ppm F)
- Immersion in 0.05% NaF mouthrinse (225 ppm F)
- Immersion in DDW (control).

A fresh strand of fluoride-impregnated floss was prepared for each sample site, as described previously. After each treatment, the teeth were rinsed in DDW to remove excess product and then stored in 100 mL of a mineralizing solution at 37° C until the next treatment. The mineralizing solution consisted of 1.5 mmol/L calcium, 0.9 mmol/L phosphate, 150 mmol/L potassium chloride, and 20 mmol/L cacodylate buffer to a pH 7.0. This solution approximates the degree of saturation by calcium phosphate minerals found in saliva, thus simulating the remineralizing stage of the caries process (Featherstone et al. 1986).

After day 7, the teeth in each acrylic block again were separated from one another with a separating disk, and a second biopsy for fluoride uptake was taken using the perchloric acid-etch enamel biopsy technique (Weatherell and Hargreaves 1965).

The difference in fluoride concentration from the initial pretreatment biopsy to the second post-treatment biopsy was reported as fluoride uptake. Summary statistics were calculated for each combination of treatment and depth. An analysis of variance followed by the least significant difference multiple comparisons procedure was used to investigate treatment differences. A P value of < 0.05 was used to indicate significant difference.

## Results

Results of fluoride analysis on the 2 terminal sites of each block were not different from those seen at the 8 proximal sites. These data were pooled for subsequent statistical evaluation. Variations in sample size among groups were due to technique errors, such as inadvertent covering of sample sites with acrylic when making the blocks.

The mean fluoride values (µgF/g enamel), for pre- and post-treatment etches, together with calculated uptake, are shown in Table 2. The results show that, although there is a wide range of fluoride levels, uptake in the experimental groups using impregnated floss is about 1.5-3 times that seen in the groups immersed in NaF mouthrinse or in DDW. Although the patterns of observed means were different for deep and shallow lesions, these differences were consistent with the hypothesis that the pattern of differences among the means is the same for deep and shallow lesions, i.e., the interaction of lesion depth and treatment was not significant. Therefore, data for deep and shallow lesions

**TABLE 2. Mean Fluoride Concentrations (ugF/g enamel) for Deep and Shallow Lesions Across Four Treatment Groups**

Deep Lesions	N	Pre-Tx	Post-Tx	Uptake <sup>a</sup>
<b>Treatment</b>				
A. NaF mouthrinse/floss	10	589 (97) <sup>b</sup>	1581(186)	992(122)
B. F dentifrice slurry/floss	10	495 (55)	1006(108)	511(139)
C. NaF mouthrinse	9	418 (39)	763 (76)	345(103)
D. DDW (control)	9	411 (54)	738 (77)	327 (93)
<b>Shallow Lesions</b>				
<b>Treatment</b>				
A. NaF mouthrinse/floss	9	689 (68)	1282 (73)	593 (36)
B. F dentifrice slurry/floss	10	558 (70)	1314(215)	756(182)
C. NaF mouthrinse	9	438 (68)	757(122)	319 (85)
D. DDW (control)	7	376 (47)	665 (78)	289 (79)

<sup>a</sup> Post-Tx - Pre-Tx = Uptake

<sup>b</sup> Mean (standard error)

were combined for subsequent statistical analysis.

Analysis of variance indicated that there was a treatment difference in the mean fluoride uptakes effected by the four treatments employed ( $P < 0.05$ ). Further statistical evaluation using multiple comparisons testing (Table 3) showed the mean uptakes resulting from application of the impregnated floss were significantly greater than those resulting from the mouthrinse alone or the control ( $P < 0.05$ ).

## Discussion

The results of this study indicate that fluoride can easily be incorporated into commercially available soft filament floss using fluoride-containing consumer products. It appears that this fluoridated dental floss may be a safe vehicle with which to deliver fluoride to the interproximal surfaces of the primary teeth in preschool children. Each strand of fluoridated floss exposes a child to only 15 µg F. In contrast, each 10.0 mL use of fluoridated mouthrinse (0.05% NaF) would expose a child to about 2250 µg F (2.25 mg F), all or most of which may be swallowed by the preschool child who may not have full control over swallowing and expectoration functions (McDonald and Avery 1983).

The primary efficacy variable of this in vitro study was the difference in fluoride uptake of demineralized human primary enamel among experimental groups treated with fluoridated floss and groups immersed in fluoridated mouthrinse or DDW. The data demonstrated a significantly greater increase in enamel fluoride concentration for the floss-treated experimental groups. The fluoridated floss groups were associated with about 1.5-3.0 times as much fluoride uptake as were the other 2 groups. These results are comparable to those of previous studies (Chaet and Wei 1977; Bohrer et al. 1983) that examined fluoride uptake by interproximal permanent molar surfaces following

**TABLE 3. Least Significant Difference Multiple Comparisons Test for Combined Fluoride Uptake Data**

Treatment	N	Mean	Grouping
A. NaF mouthrinse/floss	19	803(80) <sup>a</sup>	X <sup>b</sup>
B. F dentifrice slurry/floss	20	634 (115)	X
C. NaF mouthrinse	18	332 (65)	Y
D. DDW (control)	16	311 (61)	Y

<sup>a</sup> Mean (standard error)

<sup>b</sup> Treatments with same letter grouping are not significantly different ( $P < 0.05$ )

$\alpha = 0.05$ .

the use of fluoridated floss.

The similarities of results noted between the NaF mouthrinse and DDW are difficult to explain, as is the doubling of the fluoride concentration in the DDW control. Examination of these results with additional or replicate studies is needed.

Neither this nor the earlier in vitro studies (Chaet and Wei 1977; Bohrer et al. 1983) evaluated the form of fluoride deposited after using the fluoridated floss. Therefore, one cannot determine whether the increased fluoride levels are concentrated on the enamel surface subject to salivary washing or are incorporated into the apatite crystals of the demineralized primary enamel. Further studies in which lesions treated with fluoridated floss are assessed for mineral uptake by microhardness profiles or microradiography are obviously warranted. However, even if fluoride deposits are concentrated on the surface and subject to washing, daily use of the fluoridated floss may maintain a fluoride reservoir (Chaet and Wei 1977) on the interproximal tooth surfaces.

## Summary

Fluoridated dental floss may be a safe alternative to mouthrinses for the delivery of topical fluorides to the interproximal areas of primary teeth in preschool children. Fluoride levels associated with the use of fluoride-impregnated floss on demineralized primary enamel in vitro were significantly higher than levels associated with the use of a fluoride mouthrinse or deionized water. Further research into the exact nature of the fluoride uptake is needed.

At the time of the study Dr. Jørgensen was a postdoctoral student at Eastman Dental Center; currently she is in the private practice of pediatric dentistry in Gallipolis, Ohio. Dr. Durr is assistant chairman, pediatric dentistry, Dr. Shariati and Ms. Shields are research associates, oral biology, and Dr. Proskin is coordinator of biostatistics, all at Eastman Dental Center. Reprint requests should be sent to: Dr. David P. Durr, Dept. of Pediatric Dentistry, Eastman Dental Center, 625 Elmwood Ave., Rochester, NY 14620.

Bohrer D, Hirshfeld Z, Gedalia I: Fluoride uptake in vitro by interproximal enamel from dental floss impregnated with amine fluoride gel. *J Dent* 11:271-73, 1983.

Chaet R, Wei SHY: The effect of fluoride impregnated dental floss on enamel fluoride uptake in vitro and *Streptococcus mutans* colonization in vivo. *ASDC J Dent Child* 44:34-38, 1977.

Ericsson Y, Forsman B: Fluoride retained from mouthrinses and dentifrices in preschool children. *Caries Res* 3:290-99, 1969.

Featherstone JDB, O'Reilly MM, Shariati M, Brugler S: Enhancement of remineralization in vitro and in vivo, in *Factors Relating to Demineralization and Remineralization of Teeth*, Leach SA, ed. Oxford, England; IRL Press Limited, 1986 pp 23-34.

McDonald RE, Avery DR: Dental caries in the child and adolescent,

in *Dentistry for the Child and Adolescent*, 4th ed, McDonald RE, Avery DR, eds. St Louis; CV Mosby Co, 1983 pp 159-206.

Ripa LW, Levinson A, Leske GS: Supervised weekly rinsing with 0.2 per cent neutral NaF solution: results from a demonstrated program after three school years. *J Am Dent Assoc* 100:544-46, 1980.

Taves DR: Separation of fluoride by rapid diffusion using hexamethyldisiloxane. *Talanta* 15:969-74, 1968.

Weatherell JA, Hargreaves JA: The micro-sampling of enamel in thin layers by means of strong acids. *Arch Oral Biol* 10:139-42, 1965.

## Dental supply and demand

A comparison of dental supply and demand shows thought-provoking trends, according to *Dynamic Dental Strategies (DDS)*, the ADA's marketing newsletter.

On the supply side, the statistics reveal increased competition.

- Between 1950 and 1985, the number of active dentists increased 54%, while the general population increased 44 %.
- There are currently 60 dentists for every 100,000 persons in the U.S. This is the highest dentist-to-population ratio in American history.
- Despite a steady decline in dental school enrollment since 1975, the supply of practicing dentists will continue to increase throughout the remainder of the 20th century.

On the demand side, however, the news is more encouraging.

- More than 100 million Americans do not visit the dentist on a regular basis (at least once a year).
- 57 % of these Americans are deterred not by cost, but by their perception that they do not need to visit a dentist regularly.
- As a group, the 56 million people older than age 55 have significant dental needs. They have an annual income of \$400 million and control one-third of all discretionary consumer income in the U.S.

DDS concludes, "If all Americans who need dental care were to seek it, there would be a severe shortage of dentists. The problem is not too many dentists or too few patients—the problem is that there is much unmet need waiting to be converted into demand. That is the profession's challenge."

Advance figures from the Health Care Financing Administration show Americans spent \$500.3 billion in 1987, or \$1987/person on health care, including \$130 each for dental care. Dental spending in the same year accounted for 6.5% of the total Hospital care consumed 39%, physicians' services 20%, and nursing homes 8%.

Of the \$32.8 billion Americans spent on dental services, \$20 billion was paid out of pocket, \$12.1 billion was covered by private insurance, and \$700 million was paid by federal and state governments, mostly by Medicaid.