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Fluoride tablet programs in healthy elderly subjects: distribution of fluoride in saliva and plaque with tablets in different sites

PÅL ARNEBERG, ABU NASIR MOHAMMAD NAZMUL HOSSAIN & ASBJØRN JOKSTAD

Department of Cariology, Dental Faculty, University of Oslo, Norway

Abstract
Based on root caries data and oral sugar clearance pattern, vestibular surfaces of upper incisors and lower molars may be regarded as risk areas along with the proximal surfaces. The aim of the present study was to use this information in improving fluoride tablet programs for the elderly. Six healthy elderly males with full dental arches took part. Flavored and unflavored tablets dissolved passively either under the tongue or in the vestibule close to the root caries risk areas. Salivary fluoride was determined at five to six intra-oral sites with a micro-sampling technique at intervals up to 10 min tablet use. Plaque samples were collected from single tooth surfaces before and after tablet use, and analyzed for total fluoride and total protein by micro-techniques. Salivary fluoride exposure to root caries risk areas was strongly increased when fluoride tablets were placed in the vestibule in these areas. The unflavored tablet gave higher fluoride retention in saliva than did the flavored brand. Plaque fluoride levels tended to be above baseline in the first couple of hours after tablet use, and then to decline. In the caries risk areas, at vestibular surfaces of lower posterior and upper incisor teeth, most of the fluoride taken up in plaque had been lost after 5 h and a bread meal, whereas in the non-risk areas it was largely retained. The study demonstrated that fluoride exposures to the vestibular caries risk areas can be strongly increased by placing fluoride tablets close to them. An unflavored tablet seemed to give higher exposures than a flavored one. The rapid loss of fluoride from plaque in slow clearance risk areas indicates that more than one daily treatment would be required for elderly caries risk subjects.

Key Words: *Cariostatic agents, fluoride clearance, sodium fluoride, topical fluorides*

Introduction

The rapid increase of dentate elderly in Western societies has led to a focus on caries prevention for this group [1]. An increasing caries risk by age has been attributed to exposure of root surfaces [2] and to delayed clearance of sugar from the oral cavity [3]. The delayed clearance may result from declines by age in unstimulated salivary secretion rates [4] and oral motor function [5]. Frequent health problems and use of medications in the elderly may add to these problems [5,6].

Caries attack rates on root surfaces vary considerably in different parts of the dentition. For instance, rates are 40 times higher on vestibular surfaces of lower molar teeth than on corresponding surfaces of lower incisors, whereas the opposite pattern prevails for vestibular surfaces in the upper arch [2]. Weatherell and co-workers suggested a link between caries risk and distance from the orifices of the major salivary glands [7], and studied fluoride (F)-exposures in different areas of the dentition in rinsing and tablet programs [8,9]. Our hypothesis was that this oral clearance pattern in the elderly may be utilized for developing better F tablet programs.

The primary aim of the present study was to measure the increase in F-exposure to the caries risk areas of elderly subjects that could be obtained by placing the F-tablets close to these areas. Secondary aims were to compare exposures with flavored and unflavored tablet brands, and to study the effect of tablet site on plaque F-levels in different areas of the dentition when the flavored brand was used.

Material and methods

Subjects

The study protocol was approved by the local ethics committee. Six healthy males aged between 60 and 70

Correspondence: Professor P. Arneberg, Department of Cariology, Dental Faculty, P.O. Box 1109, Blindern, NO-0317 Oslo, Norway. Tel: +47 48 22 42 86 66. Fax: +47 48 22 85 23 44. E-mail: paala@odont.uio.no

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Table I. Fluoride tablets

Tablet		'Fluor-a-day' Dental Health Promotion Ltd, London		'Flux' Alpharma, Oslo, Norway	
F-content/tablet		1 mg		0.25 mg	
Tablet size		6 × 2.2 mm		9 × 4 mm	
Flavor		No flavor		Sorbitol 150 mg Xylitol 155 mg Mint	
Dose = 0.75 mg F		3 × 1/4 parts		3 tablets	
Tablet placed		In lower[1] vestibules	Under tongue	In lower[1] vestibules	Under tongue
Intra-oral dissolution time	Mean	17.3	8.7	42.2[2]	20.7
	(SD)	(3.3)	(1.0)	(5.2)	(4.8)

[1] Tablet remnants upper labial site were always removed on dissolution of the lower ones.
[2] In three subjects, small remnants of Flux tablets in lower vestibules were removed at 45 min.

years with full dental arches volunteered. All subjects had a high number of restored teeth, and one (a) had a history of active caries lesions in recent years. Oral hygiene and F-products were not used in the 4 days prior to experiments.

Saliva flow rates

Unstimulated and stimulated salivary flow rates were determined as described previously [10].

F-programs

One flavored and one unflavored F-tablet brand were tested (Table I). In one experiment with each brand the whole dose was placed in the sublingual area. In the other experiment, the tablets (or tablet parts) were distributed in the vestibule, with one below the second lower molar tooth on each side, and the third above the 1st right upper central incisor. The tablet (part) dissolved more slowly in this latter site, and its remnant was removed when those in the lower vestibule had dissolved, in order to have a common starting time for clearance measurements. A maximum of 45 min was allowed for tablet dissolution (Table I). An experiment with a 1-min rinse with 10 ml of a 0.05% sodium fluoride solution (226 ppm F) was included as a control.

Salivary F-clearance test

The subjects were seated upright in a dental chair, swallowing *ad libitum*. Circular pieces (5 mm) of Whatman paper, had been pre-weighed with the test tube. The papers were placed at five or six intra-oral sites 1 min prior to the recorded time; starting in the vestibule above tooth number 16, followed by teeth 46, 42, 21, ending in the sublingual area close to the papilla. Sites at teeth 12 (tablet side) and 36 were also sampled in some experiments, but the results were not included in the tables, figures, or statistical analyses. Sampling was performed twice with tablets in the mouth and at 2, 6, and 10 min thereafter. The weight of the wet paper in the sealed tube was determined within 30 min. In a few experiments, weights were not obtained owing to problems with the micro-balance. Saliva amounts in these experiments were estimated from mean uptake in different sites, which ranged from about 15 mg sublingually to about 3 mg in the upper labial site.

Plaque sampling

Visible amounts of vestibular plaque from incisor and molar teeth were collected with a narrow (1 mm) edge of a plastic coverslip, saving vertical stripes of plaque for the subsequent samplings. Vestibular plaque from upper incisors and lower molars were grouped as risk *(RISK)* samples, and those from lower incisors and upper molars as non-risk *(NON-RISK)*. The proximal spaces of molar teeth in both arches and the lingual surfaces of lower molar teeth were sampled with a probe that had been ground flat on one side. These sites could rarely be re-sampled. In experiments with subjects a, e, f, and p, plaque was collected four times (before, and at 1, 2, and 5 h after tablet placement). However, because of insufficient plaque amounts in several samples, and to minor differences between 1 and 2 h plaque F, these two were substituted with a single sampling 1 h after the tablet had dissolved in experiments with subjects h and k. A lunch meal with sandwiches and sugar-free coffee or water was always taken 3–4 h after tablet use.

Saliva and plaque analyses

F from saliva and plaque was extracted for 2 h at 20°C during agitation. Saliva was extracted in 2.5–0.25 ml of the F standard buffer (low level TISAB buffer pH 5.2 containing 0.25 N of both perchloric acid and sodium hydroxide). Plaque was extracted in 10 µl of the perchloric acid, neutralized with 10 µl of the sodium hydroxide in (double strength) buffer, and controlled by spot test on narrow range pH paper. Aliquots (0.4 µl) of the extracts were analyzed under oil on an inverted F-electrode [11], together with aliquots of 1,

0.1, and 0.01 ppm F-standards. The log-linear standard curve had a slope of 60–64 mV between the 1 ppm and the 0.1 ppm F standards. This slope was used for computer calculation of F in plaque extracts. The 0.01–0.1 ppm slope was 13–18 mV lower, due to a strong curve deviation below 0.03 ppm, caused by F-contaminants in the reagents and from the 0.01 ppm F washing solution. To avoid a systematic overestimation by about 100% on the 0.01 ppm level, 0.01 ppm was subtracted from all plaque extract values in the computer calculation. A significant proportion of plaque extracts at baseline (10–53%) was below the 0.03 ppm level. For plaque mass assessment, the plaque pellet was digested in 4 N of sodium hydroxide at 90°C for 30 min, neutralized and quantified *in duplo* for total protein by a sensitive colorimetric test (BCA method; Pearce Chemical Company, Rockford, Ill., USA). The analysis was carried out in micro-titer trays with albumin as standard. Color was developed for 30 min at 60°C under cover and quantified in an automatic scanner at 560 nm. The protein was assumed to account for 5% of the plaque wet-weight [12]. Samples with <0.2 mg plaque (<10 μg plaque protein) were excluded. In an average-sized sample of 0.5 mg plaque, an extract value of 0.025 ppm F in the 20 μl extract gives 1 ppm plaque F. Some plaque samples, mainly from *RISK* areas at baseline, were found to contain <0.1 ppm F. The plaque F in these samples was recorded as 0.1 ppm, since discrimination between standards below 0.005 ppm was poor.

Data analysis

Weights of the saliva samples and protein amounts in the plaque samples together with corresponding mV readings of F-extracts and F-standards were entered into SPSS data files. Syntax files were made for calculation of plaque amounts, and F-concentrations in plaque and local saliva at different times in the experiments. The local salivary F-exposures (ppm × min) during and up to 10 min after tablet dissolution were calculated and matched with plaque F-levels and F-concentration changes within the area in the same experiment.

Paired *t*-tests based on a single observation from same site in each subject ($n=6$) were used for comparing F-levels in local saliva and local F-exposures in different F-programs. An unpaired *t*-test was used for comparing changes in plaque F within subjects, and a paired *t*-test for changes in plaque Log F within tooth surfaces. Pearson's *r* was used to calculate the relationship between salivary flow rates and tablet dissolution rates, as well as that between local F-exposure during tablet treatment and plaque F uptake.

Results

Salivary flow and tablet dissolution rates

Wide ranges of salivary flow rates were observed (Table II). The bulky and flavored *FLUX* tablets took about twice as long time to dissolve as did the much smaller parts of the unflavored *F-A-DAY*, and for each brand dissolution took about twice as long in the lower vestibule as under the tongue (Table I). In the upper labial vestibule, tablets dissolved even more slowly. With both brands, high salivary flow rates tended to speed up dissolution rates in the sublingual area (data not shown).

Table II. Age and salivary flow rates of the six test subjects

	Age[1] in years	Unstimulated flow (ml/min)	Stimulated flow (ml/min)
Mean (SD)	66.6 (3.6)	0.23 (0.13)	2.00 (0.69)
Minimum–maximum	60–71	0.12–0.48	0.95–2.90

[1] Age correlated negatively with unstimulated and stimulated flow rates. (Pearson's $r=-0.95$ and -0.80; $p<0.01$ and >0.05, respectively.)

Local salivary F-levels and exposures

The local concentrations after F-treatments varied several thousand times, and were influenced by time, intra-oral area, tablet brand, tablet site, and subject, whereas a repeated experiment gave fairly consistent results (data not shown). Figure 1 shows the changes over time in the sublingual area and in the lower posterior vestibule for each program. F-levels were highest close to the dissolving tablets; that is sublingually with tablets in this site, and in the lower vestibule with tablet in that site, but this effect of tablet site had become slight in the final 10 min samples. It can be seen that the F cleared away several times more rapidly from the sublingual area than from the lower vestibules, and also that final levels in both areas were about one log unit higher after use of the unflavored *F-A-DAY* tablets than after the flavored *FLUX* (Figure 1).

Accumulated exposure up to 10 min after treatment varied according to subject, area, tablet site, and brand, with a total range of 0.1–32.9 (10^{-3} ppm × min). In the *RISK* area of the lower posterior vestibule, exposures were higher with the unflavored *F-A-DAY* tablet than with the flavored *FLUX*, and with each brand higher with tablets in the vestibular than in the sublingual site (Table III). With the tablets placed on the other side of the upper labial frenulum, exposures tended to be below those in the lower posterior vestibule (Table III), but this was not the case in five experiments when the tablet side was sampled (data not shown).

F-levels 10 min after treatment are given in Table IV. All oral areas tended to show a lower F-retention after the flavored *FLUX* than after the unflavored *F-A-DAY*. In some experiments, essentially no clearance could be detected in the upper labial area within this time (data not shown).

Plaque findings

Shortly (1–2 h) after use of the flavored *FLUX* tablets in sublingual or vestibular sites, median plaque

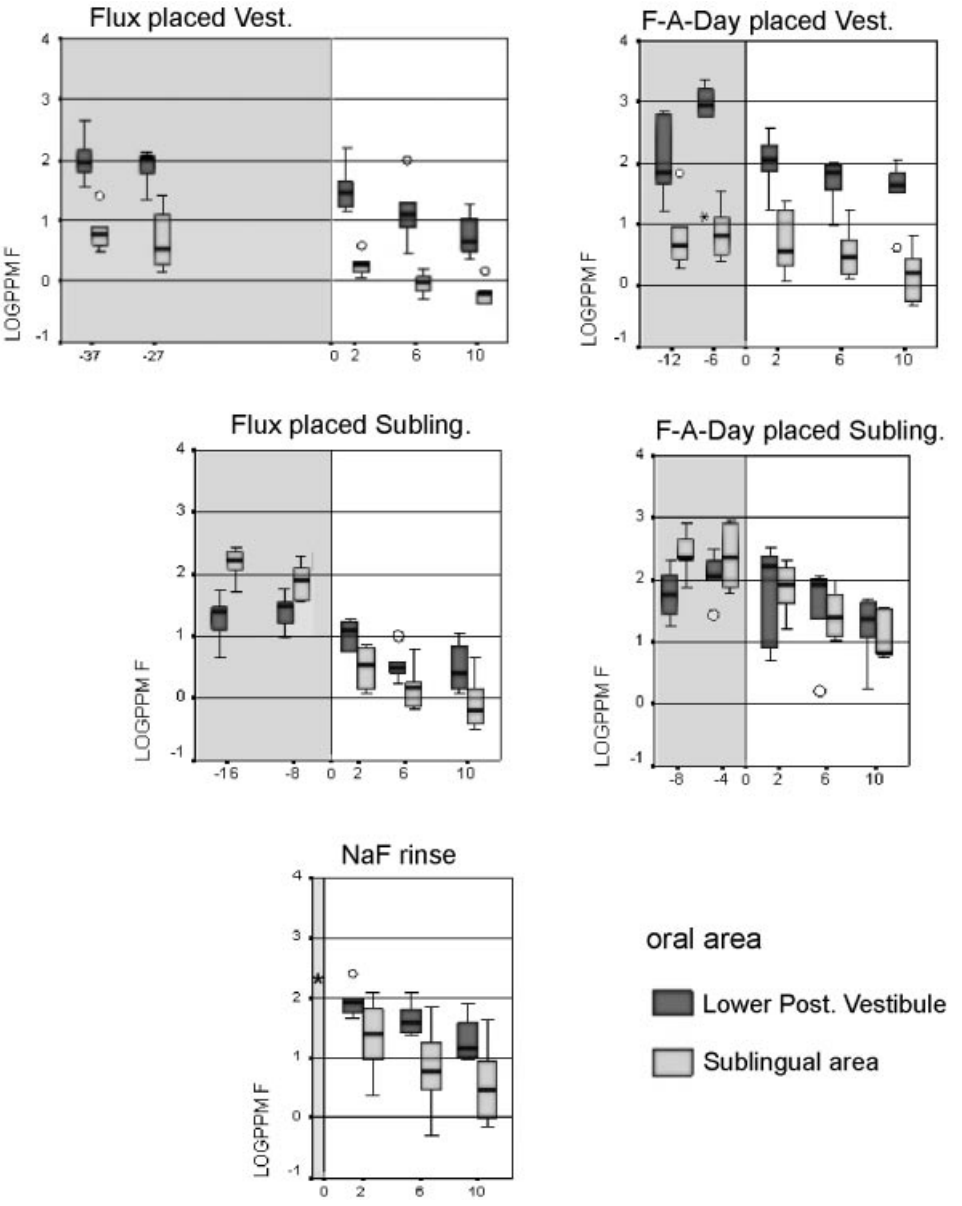

Figure 1. Changing salivary F-levels over time in two oral areas in the tablet and rinsing programs. Median, quartiles, and extreme values based on one observation from each test subject in each site ($n=6$). Note log scales. Shaded areas give approximate tablet dissolution times; mean SD given in Table I. *F-levels during 1 min rinsing experiments recorded as 80% of the rinsing solution concentration.

F tended to be higher than baseline, and at 5 h levels were closer to baseline again (Table V). However, in most experiments, plaque F uptake was not statistically significant owing to a low number of samples and variable plaque levels from site to site at most time-points (coefficients of variation 60–239%). Tablet placement in the vestibules or in the sublingual area showed no apparent effect upon individual mean plaque F-levels (Table IV. A, B). On the other hand, the paired observations from the same tooth surface within experiments indicated a significant plaque F uptake in vestibular *RISK* areas with tablets close to them, and essentially no uptake with tablets in the sublingual site (Table VI). However, the data pairs in this analysis were few, and baseline F-levels sometimes too low to be determined precisely.

The plaque F-level or -uptake could not, in any subject, be shown to increase by increasing salivary F-exposure to the local area during tablet use. On the contrary, the relationship between these parameters was more often negative (Pearson's $r=-0.3$; $p<0.05$; for sites in all subjects).

Plaque F at vestibular *NON-RISK* surfaces tended to be higher than at corresponding *RISK* surfaces, and this difference was quite pronounced at the final sampling after 5 h (Table VII). Also lingual (*NON-RISK*) plaque tended to retain more F than did proximal (*RISK*) plaque, but for these surfaces paired data were not available (data not shown).

Table III. Fluoride exposure (ppm F × min × 10^{-3}) in different oral areas according to tablet brand and tablet site. Mean (SD) during treatment and up to 10 min after

	Tablet site				
	Sublingually		In vestibule		
Sampling area	*FLUX*	*F-A-DAY*	*FLUX*	*F-A-DAY*	*F-RINSE*
NON-RISK					
Sublingual	2.7 (1.5)[a,d]	3.6 (3.0)[a,d]	0.3 (0.3)	0.3 (0.4)	0.4 (0.3)
Lower front	1.0 (0.7)	1.7 (1.5)	2.0 (3.4)	1.1 (1.1)	1.0 (1.0)
Upper posterior	0.6 (0.5)	0.9 (0.6)	0.6 (0.2)	1.0 (0.8)	0.7 (0.5)
RISK					
Lower posterior	0.7 (0.5)	1.8 (0.8)[b]	5.8 (3.3)[a,d]	13.3 (12.2)[a,b,d]	0.8 (0.5)
Upper front	0.4 (0.3)[c]	1.8 (2.3)	3.2 (2.6)[a]*	2.0 (3.7)*	1.3 (1.0)
All sites	1.1 (1.1)	2.0 (2.0)[b,d]	2.4 (3.0)[a,d]	3.5 (7.3)	0.8 (0.7)

$p < 0.05$ in paired *t*-test with log-transformed values: [a] higher than same tablet at other site; [b] *F-A-DAY* higher than *FLUX* at same site; [c] lower than F-rinse; [d] higher than F-rinse.
* Sampled on the non-tablet side of the upper labial frenulum.

Discussion

The present findings support the hypothesis that caries risk in the elderly due to declines in oral clearance might be compensated by F-tablet programs that increase F-exposure to caries-prone areas in the dentition. The clearance patterns in our healthy elderly subjects seemed more favorable than in an older group with frequent health problems [5] and agrees largely with findings in adults [7,8]. In accordance with an F-rinsing study [8], there seemed to be considerable differences in clearance among intra-oral areas and subjects (Figure 1) with more consistent rates within areas. A faster clearance from the sublingual area than from the lower posterior vestibules (Figure 1) is in accordance with findings in adults [8] as well as in rheumatic patients with dry mouth symptoms [4]. In these patients, unstimulated salivary flow rates were directly related to clearance rates, which, in turn, were inversely related to counts in microbiological caries tests and to number of root caries lesions; indicating a direct impact upon dental plaque ecology and dental caries [4].

With an F-A-DAY tablet in the upper labial site, Primoch et al. [7] found a peak concentration of about 4000 ppm, and a total exposure equivalent to 1000 ppm F for more than 1 h on the tablet side, which would correspond to an exposure above 60 in our data. Even though, in the present experiment, the local dose was lower, dissolution was interrupted at this site, and sampling time was shorter, remarkably high final levels were sometimes recorded even on the non-tablet side in this stagnant area (Table IV). For posterior teeth, this pattern was the reverse, showing a faster clearance from the upper than from the lower vestibule (Table IV), in accordance with plaque pH-curves in these areas after glucose rinsing [9].

McCall et al. [13] found higher salivary F-levels and also higher total exposures with the unflavored (F-A-DAY) tablet than with flavored tablets when measuring F-levels in expectorates. The present findings indicate that this applies even more strongly to the caries *RISK*

Table IV. Fluoride levels in salivary samples from different oral areas 10 min after treatment. Mean (SD) ppm F

	Tablet site				
	Sublingually		In vestibule		
Sampling area	*FLUX*	*F-A-DAY*	*FLUX*	*F-A-DAY*	*F-RINSE*
NON-RISK					
Sublingual	1.3 (1.6)	15.6 (14.5)[a,b]	0.7 (0.4)[c]	2.3 (2.3)	9.8 (16.1)
Lower font	3.3 (1.9)	26.2 (31.7)[a,b]	5.9 (4.2)[c]	10.4(7.4)	25.0 (27.8)
Upper posterior	2.2 (1.0)[c]	17.5 (14.6)[b]	4.7 (2.3)[a,c]	17.1 (14.4)	20.3 (9.3)
RISK					
Lower posterior	4.3 (4.0)[c]	25.5 (18.4)[b]	7.4 (6.3)[a,c]	50.4 (37.4)[b]	27.2 (26.3)
Upper front	7.1 (11.7)[c]	27.3 (22.1)[b]	32.0 (39.2)*	165.2 (259.0)*	44.4 (32.8)
Total	3.6 (5.6)[c]	22.4 (20.3)[b]	10.2 (20.1)[c]	49.1 (125.0)[d]	25.3 (25.1)

$p < 0.05$ in paired *t*-test with log transformed values: [a] higher than same tablet at other site; [b] higher than *FLUX* at same site; [c] lower than F-rinse; [d] higher than F-rinse.
* Sampled on the non-tablet side of the upper labial frenulum.

Table V. Effect of F-tablet programs on plaque F after 1–2 and 5 h. Median ppm F, range, and number of samples (*n*) from all sites in each subject

Time after tablet placement	Subjects						
	a	e	f	h	k	p	Total
A. FLUX tablets in vestibule							
Baseline (0 h)	3.3	2.3	1.0	11.5	1.8	–	2.6
	0.4–18.5	0.1–11.9	0.2–41.5	0.1–72.5	0.1–32.4	–	0.1–72.5
	$n=8$	$n=15$	$n=10$	$n=9$	$n=12$	$n=0$	$n=54$
Short time (1–2 h)	13.2*	4.7*	5.7	16.0	11.4	14.4	9.1*
	1.6–141.6	0.1–43.7	0.9–22.8	1.2–79.5	1.0–42.3	1.1–28.1	0.1–141.6
	$n=19$	$n=23$	$n=12$	$n=11$	$n=11$	$n=7$	$n=83$
Intermediate time (5 h)	2.8	3.5	–	11.7	3.4	–	4.6
	0.1–82.1	0.1–51.3	–	0.5–96.5	0.1–73.3	–	0.1–96.5
	$n=10$	$n=21$	$n=0$	$n=15$	$n=20$	$n=0$	$n=66$
B. FLUX tablets sublingually							
Baseline (0 h)	1.6	8.8	0.3	12.0	1.1	0.9	1.4
	0.1–11.5	0.8–44.2	0.1–1.3	1.4–107.2	0.1–37.3	0.1–6.3	0.1–107.2
	$n=7$	$n=5$	$n=8$	$n=7$	$n=9$	$n=4$	$n=40$
Short time (1–2 h)	16.9*	11.7	4.0*	13.1	19.5	3.3	6.3*
	0.2–180.0	0.8–77.5	0.6–32.3	1.9–92.8	0.2–24.4	0.4–43.5	0.2–180.0
	$n=14$	$n=16$	$n=16$	$n=8$	$n=7$	$n=8$	$n=69$
Intermediate time (5 h)	7.6	10.1	1.6	8.0	9.0	1.8	8.1
	1.2–50.2	2.1–128.6	0.3–33.0	0.3–43.9	0.1–66.3	0.2–4.7	0.1–128.6
	$n=7$	$n=9$	$n=7$	$n=15$	$n=13$	$n=4$	$n=54$

* Different from baseline by *t*-test for two independant samples $p<0.05$.

areas (Figure 1, Tables III and IV). The tablet flavor most likely increases the clearance by speeding up secretion rates and salivary film velocity [3]. F-tablet flavor was considered important for compliance in children [13], but might not play as great a role in elderly subjects with a caries problem. Based on the present findings, unflavored tablets, small in size, and with the solubility characteristics of F-A-DAY, but with a lower F-dose (Table I) would appear promising for increasing F-exposure in elderly risk-subjects. Placement in the vestibule increases the exposure to risk areas, but side effects on the mucous membranes of dry mouth patients might be a risk, particularly with tablets in the upper labial site [7].

The success of topical F-programs has been attributed to build-up of local calcium fluoride or tooth mineral stores in, or close to, the caries lesion, capable of releasing free F-ions during low pH periods [14–17]. Plaque may represent such an F-releasing store. However, the present data did not convincingly demonstrate that the increase in F-exposure obtained by placing tablets close to the *RISK* areas gave a corresponding increase in plaque F during the first few hours after use, even though the paired data would indicate such an effect (Table VI). Plaque mass assessment by a colorimetric protein test [12] and F-analysis under oil [11] are both sensitive and reproducible, even though plaque levels <0.5 ppm F should

Table VI. Relative changes in plaque F within vestibular *RISK* and *NON-RISK* areas according to tablet program. Mean (SE) of paired difference in Log F at same site during experiment

Period	Total	Both tablet programs		Sublingual tablets		Vestibular tablets	
		Non-risk surfaces	Risk surfaces	Non-risk surfaces	Risk surfaces	Non-risk surfaces	Risk surfaces
Baseline to 1–2 h	+0.49**	+0.65**	+0.31*	+0.79**	+0.13	+0.48	+0.54*
	(0.12)	(0.19)	(0.12)	(0.27)	(0.10)	(0.27)	(0.24)
	$n=48$	$n=25$	$n=23$	$n=14$	$n=13$	$n=11$	$n=10$
Baseline to 5 h	+0.55**	+0.85**	+0.21	+0.73*	+0.02	+0.98**	+0.41
	(0.09)	(0.20)	(0.20)	(0.27)	(0.28)	(0.20)	(0.28)
	$n=32$	$n=17$	$n=15$	$n=9$	$n=7$	$n=8$	$n=8$
1–2 to 5 h	−0.14	+0.06	−0.33**	+0.02	−0.46*	+0.13	−0.24
	(0.15)	(0.16)	(0.10)	(0.20)	(0.15)	(0.19)	(0.13)
	$n=49$	$n=24$	$n=25$	$n=15$	$n=10$	$n=9$	$n=15$

Data pairs (*n*) pooled from all subjects.
Different from zero by *t*-test: * $p<0.05$, ** $p<0.01$.

Table VII. Plaque ppm F at vestibular RISK and NON-RISK areas by subject and time. Mean (SD). Pooled, unpaired data from experiments with FLUX tablets in sublingual and in vestibular site

Subject	Area	Baseline		1–2 h		5 h	
a	*NON-RISK*	($n=4$)	6.4 (8.2)	($n=8$)	45.0 (47.5)	($n=4$)	56.9 (18.9)**
	RISK	($n=4$)	7.2 (4.6)	($n=11$)	15.0 (13.7)	($n=7$)	7.3 (9.3)
e	*NON-RISK*	($n=5$)	4.2 (3.1)	($n=10$)	25.5 (27.0)	($n=9$)	36.2 (42.8)*
	RISK	($n=6$)	6.5 (7.3)	($n=13$)	9.4 (9.6)	($n=9$)	4.2 (4.2)
f	*NON-RISK*	($n=5$)	8.6 (18.4)	($n=9$)	8.7 (11.2)	($n=2$)	16.9 (22.7)
	RISK	($n=3$)	0.6 (0.6)	($n=8$)	3.2 (2.8)	($n=1$)	1.6
h	*NON-RISK*	($n=6$)	14.4 (7.6)**	($n=9$)	23.1 (26.6)	($n=11$)	14.6 (11.4)**
	RISK	($n=4$)	2.3 (3.4)	($n=6$)	4.5 (2.4)	($n=10$)	3.6 (4.1)
k	*NON-RISK*	($n=9$)	12.5 (14.4)	($n=7$)	27.4 (14.9)**	($n=14$)	21.7 (23.7)
	RISK	($n=8$)	3.4 (3.6)	($n=8$)	5.4 (7.6)	($n=14$)	10.4 (20.3)
p	*NON-RISK*	($n=2$)	3.7 (3.6)	($n=7$)	18.0 (14.7)	($n=2$)	2.5 (3.1)
	RISK	($n=3$)	1.7 (2.3)	($n=7$)	6.0 (5.4)	($n=2$)	1.8 (1.8)
All	*NON-RISK*	($n=31$)	9.5 (11.6)*	($n=50$)	24.4 (27.7)**	($n=42$)	25.2 (28.2)**
	RISK	($n=28$)	4.0 (4.7)	($n=53$)	8.7 (9.4)	($n=43$)	6.4 (12.5)

n = Number of samples.
Difference by t-test for two independent samples; * $p<0.05$, ** $p\leq 0.01$.

be considered as semi-quantitative. Moreover, the sampling program proved too ambitious in relation to the variable plaque amounts and the low number of subjects (Table V).

Interestingly, the F taken up in plaque in oral areas with low caries risk was largely retained after 5 h and a single bread meal, whereas that in *RISK* areas had been released (Tables VI and VII). The release seems faster than from plaque at corresponding surfaces in children from Bangladesh, in whom plaque F in these sites was elevated 24 h after the same tablet dose [18]. Age-related differences in oral clearance may have contributed, along with differences in diet and oral size, and also the fact that the children were in a continuous daily program whereas our elderly were F-depleted.

A faster release of Plaque F from *RISK* areas than from *NON-RISK* areas is in accordance with observations from upper and lower posterior teeth in adults [19], and also consistent with observations from upper and lower front teeth in orthodontic patients [12]. In the latter study, the low plaque F was found related to a low plaque pH. Microbial selection in the low pH plaque increases its pH-depressing capacity [4,20]. It may thus seem that a low plaque pH in areas where the oral sugar clearance is slow induces ecological changes that deplete the plaque mineral reservoirs [16,21] and result in few or weak F-binding sites. Further studies of such intra-oral patterns and site-related differences may improve our understanding of plaque ecology, and the role of fluoride in caries prevention.

Most studies on preventive programs have investigated total caries increment in young subjects. We have tried to bring caries *RISK* areas and the elderly into focus. The main finding of the present study was that high F-exposures to vestibular caries *RISK* areas in the elderly can be obtained by passive dissolution of a low-dose F-tablet close to them. Limitations of the study are that salivary F-exposures to the proximal *RISK* surfaces were not measured and that its caries-preventive potential was not evaluated. However, a 5000 ppm F-toothpaste proved clearly superior to one with 1100 ppm in re-hardening and re-mineralizing existing root caries lesions, supporting a dose–effect relationship also in this type of caries [22]. Based on root caries distribution [2], and typical tooth loss pattern in the elderly [23], we believe that a high F-exposure to lower molar teeth may be important for retaining these teeth in the elderly. The present study supports that non-flavored tablets give higher F-exposures than flavored tablets [13]. The short plaque F-retention time, found in the slow clearance *(RISK)* areas of fairly caries-inactive subjects, suggests that F-retention time might be even shorter in the truly caries actives, and that frequent F-treatments would be useful for them.

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References

[1] Powell LV, Persson RE, Kiyak HA, Hujoel PP. Caries prevention in a community dwelling older population. Caries Res 1999;33:333–9.

[2] Katz RV, Hazen SP, Chilton NW, Mumma RD. Prevalence and intra oral distribution of root caries in an adult population. Caries Res 1982;16:265–71.

[3] Dawes C. A mathematical model of salivary clearance of sugar from the oral cavity. Caries Res 1983;17:321–34.

[4] Risheim H, Arneberg P, Birkhed D. Oral sugar clearance and root caries prevalence in rheumatic patients with dry mouth symptoms. Caries Res 1992;26:439–44.

[5] Hase JC, Birkhed D, Grennert ML, Steen B. Salivary glucose clearance in elderly people. Gerodontics 1987;3:146–50.

[6] Närhi TO, Meurman JH, Ainamo A, Nevalainen JM, Schmidt-Kaunisaho KG, Siukosaari P, et al. Association between salivary flow rate and the use of systemic medication among 76-, 81-, and 86-year-old inhabitants in Helsinki, Finland. J Dent Res 1992;71:1875–80.

[7] Primosch RE, Weatherell JA, Strong M. Distribution of salivary fluoride from a sodium fluoride tablet following various intra-oral dissolution methods. J Dent Res 1986; 65:1001–5.

[8] Weatherell JA, Strong M, Ralph JP, Robinson C. Fluoride distribution in the mouth after fluoride rinsing. Caries Res 1986;20:111–9.

[9] Weatherell JA, Duggal MS, Robinson C, Curzon MEJ. Site specific differences in human dental plaque pH after sucrose rinsing. Archs Oral Biol 1988;9:493–516.

[10] Arneberg P, Storhaug K, Sandvik L. Effect of a slow release transcutaneous scopolamine application on salivary flow, buffering action and on salivary levels of streptococcus mutans and lactobacilli. Scand J Dent Res 1989;97:408–14.

[11] Vogel GL, Carey CM, Chow LC. Fluoride analysis in nanolitre and microlitre size samples. J Dent Res 1990;69:522–8.

[12] Arneberg P, Giertsen E, Emberland H, Ögaard B. Intra-oral variations in total plaque fluoride related to plaque pH. A study in orthodontic patients. Caries Res 1997;31:451–6.

[13] McCall D, Stephen KW, McNee SG. Fluoride tablets and salivary fluoride levels. Caries Res 1981;15:98–102.

[14] Fejerskov O, Thylstrup A, Larsen MJ. Rational use of fluorides in caries prevention. Acta Odontol Scand 1981;39: 241–9.

[15] Rölla G, Saxegaard E. Critical evaluation of composition and use of topical fluorides with special emphasis on the role of calcium fluoride in caries prevention. J Dent Res 1990;69: 780–5.

[16] Pearce EIF. Relationship between demineralization events in dental enamel and the pH and mineral content of plaque. Proc Finn Dent Soc 1991;87:527–39.

[17] Rose RK, Shellis RP, Lee AR. The role of cation binding in microbial fluoride binding. Caries Res 1996;30:458–64.

[18] Nazmul Hossain ANM, Sampaio FC, von der Fehr FR, Arneberg P. Changes in plaque fluoride levels by school based fluoride rinsing and tablet programs in Bangladesh. Acta Odontol Scand 2003;61:34–8.

[19] Vogel GL, Mao Y, Chow LC, Proskin HM. Fluoride in plaque fluid, plaque, and saliva measured for 2 hours after a sodium fluoride monofluorophosphate rinse. Caries Res 2000;34: 404–11.

[20] Bradshaw DJ, McKee AS, Marsh PD. Effects of carbohydrate pulses and pH upon population shifts within oral microbial communities in vitro. J Dent Res 1989;68:1298–302.

[21] Whitford GM, Wasdin JL, Schafer TE, Adair SM. Plaque fluoride concentrations are dependent on plaque calcium concentrations. Caries Res 2002;36:256–65.

[22] Baysan A, Lynch E, Ellwood R, Davies R, Petersson L. Reversal of primary root caries using dentifrices containing 5,000 and 1,100 ppm fluoride. Caries Res 2001;35:41–6.

[23] Arneberg P, von der Fehr FR, Bjertness E. Caries and defective restorations in elderly faculty patients. A follow-up study. Gerodontics 1988;4:224–8.