

# Fluoride ingestion from toothpaste: fluoride recovered from the toothbrush, the expectorate and the after-brush rinses

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**Abstract – Objectives:** The aim of this study was to determine the effects of rinsing and spitting on fluoride ingestion from toothpaste during normal oral-hygiene procedures of younger children, and hence to make recommendations on rinsing during toothbrushing. **Methods:** The brushing habits of 166 Dutch and 185 Irish children between 1.5 and 3.5 years were observed during home visits. The weight of the toothpaste tube was determined before and after use. After brushing, the toothbrush and any associated expectorate and rinses, combined with any toothpaste spilled during the brushing procedures, were collected. The amounts of fluoride retained on the toothbrush and in the associated expectorate and rinses were measured. **Results:** Over 90% of the Dutch children used a special toddlers' toothpaste with  $\leq 500$  ppm F. Eleven per cent of the younger (<2.5 years) Dutch children and 22% of the older children rinsed after brushing. Of the Irish children approximately 52% used a children's toothpaste containing around 500 ppm F. Of the younger Irish children 31% spat without rinsing, while another 31% rinsed during or after brushing. For the older Irish children, these percentages were 14 and 70%, respectively. On average, 22% of the fluoride dispensed on the toothbrush was retained on the brush after brushing irrespective of the rinsing and spitting behaviour of the children. The maximum ingestible amount of fluoride from toothpaste assuming no rinsing or spitting was calculated. **Conclusions:** Fluoride ingestion from toothpaste is significantly reduced by rinsing and/or spitting during toothbrushing. Recommendations that younger children use small amounts of toothpaste (<0.5 g) and that children using toothpaste with  $\geq 1000$  ppm F rinse their mouths after brushing continue to be valid.

**Key words:** children; dental fluorosis; fluoride ingestion; rinsing and spitting; toothpaste

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After-brushing rinses are routinely advised by the dental profession to remove debris and to avoid swallowing excess fluoride toothpaste. In a study of the oral health-care habits of 1- to 4-year-olds from day-care centres in Iowa ( $n = 59$ ), Levy et al. (1) found that only 5% of the children under 2.5 years of age and 32% of the children aged 2.5 to 4 years rinsed their mouths after toothbrushing. Twenty-

seven per cent of all the children in that study rinsed but swallowed all or almost all of the rinse. These results confirm an earlier suggestion that many children are not capable of rinsing their mouth during toothbrushing (2). Other recent studies have shown that thorough rinsing after toothbrushing may have an adverse effect on the caries-preventive effect of the fluoride in toothpaste (3–5). Therefore, it

may seem justifiable not to teach young children to rinse their mouths thoroughly after brushing. Little research has been conducted on the amounts of toothpaste, and fluoride, that can be recovered from the toothbrush after brushing. If toothpaste retained on the toothbrush is the bulk of toothpaste that is not swallowed, then additional after-brushing rinses may not be necessary. In adults, Sjögren et al. (6) observed that approximately one-third of toothpaste used during brushing is retained on the toothbrush. The aim of the present study was to measure the proportion of fluoride that was retained on the toothbrush and in the expectorate, including the after-brushing rinses, during toothbrushing of young children 1.5 to 3.5 years of age and, thereby, to determine the effects of rinsing and spitting on fluoride ingestion from toothpaste and hence the importance of after-brush rinsing.

## Materials and methods

Approval for the study was obtained from the local research ethic committees both in Amsterdam, the Netherlands and in Cork, Ireland.

In the Netherlands, 166 children between 1.5 and 3.5 years of age were visited in the city of Haarlem and the surrounding area, representing 4.7% of the total population of this age group in this district. In the city of Cork, Ireland, 175 children between 1.5 and 3.5 years of age, or 5.6% of this population, were visited. The names of the children were obtained from the birth register of each city. The children, who were all participants in a multicentre European study, 'Project FLINT' (7), were chosen randomly as reported earlier (8). Briefly, the children were sorted by dates of birth and to every tenth child a letter was sent asking for permission to contact the family. If there was a negative or no reply, the following child on the chronological list was invited. At the first visit the parents were invited to sign a letter of consent.

The children were visited at home and the children and parents/caretakers were asked to brush the child's teeth in their normal way. For this, the visiting investigator provided a tube of toothpaste, pre-weighed to the nearest 0.01 g, and a new toothbrush, each of the brand and type normally used by the child, deionized water for rinsing and a receptacle for collecting the expectorate. When observing the procedure, the investigator kept at a distance so as not to disturb the normal family routine. The used

toothbrush and expectorate including any rinses (with deionized water) were collected and transported back to the laboratory in separate sealed plastic containers (9). If a child spilled any toothpaste, an attempt was made to recover it and to add it to the collected expectorates and rinses. The tube of toothpaste was then re-weighed to the nearest 0.01 g. The toothbrush was carefully rinsed with deionized water and placed in an ultrasonic cleaner to wash out all remnants of toothpaste. The two resulting solutions of (i) water with toothpaste from the brush, and (ii) the associated expectorate sample, for each subject were separately stored at  $-20^{\circ}\text{C}$  prior to fluoride analysis in one central laboratory (Cork).

During the home visits the parents were also asked for further details of their children's brushing habits using a structured questionnaire, and the children were weighed to the nearest 100 g (8).

### *Fluoride measurements*

The fluoride measurements are detailed elsewhere (9). The fluoride concentration in the toothpaste used by the children, the solutions obtained from washing the toothbrushes, and the samples of expectorate were measured with a fluoride ion-specific electrode 720 A series (Orion Research, MA) after dilution and filtration (0.2- $\mu\text{m}$  pore filter) in Total Ionic Strength Adjustment Buffer (TISAB). Samples containing sodium monofluorophosphate were first hydrolysed for at least 3 h at  $37^{\circ}\text{C}$  by the addition of sodium acetate (final concentration 10 mmol/L; BDH Analar Grade, BDH Chemicals Ltd, Poole, UK) and acid phosphatase (final concentration: 0.5 U/mL; Sigma code P1146, Sigma Chemicals, St Louis, MO) (10).

### *Statistical analysis*

All data were analysed by multivariate analysis of variance (MANOVA) with 95% confidence using the Generalised Linear Model Multivariate with the Tukey *post hoc* test (SPSS version 8.0).

## Results

Parents of a total of 341 children answered the questionnaire on toothbrushing habits. Of the 166 Dutch children in the sample, 97 were in the younger age group (1.5–2.5 years) and 69 were in the older group (2.5–3.5 years). In Cork the respective numbers were 60 and 115. Table 1 shows the reported rinsing and spitting behaviour and the reported

Table 1. Reported rinsing and spitting behaviour and reported toothbrushing advice given for the children in each study group

	the Netherlands		Ireland	
	1.5–2.5 yr (n = 97)	2.5–3.5 yr (n = 69)	1.5–2.5 yr (n = 60)	2.5–3.5 yr (n = 115)
Question: Does your child spit out during or after brushing?				
Yes, always	10 (10%)	20 (29%)	8 (13%)	60 (52%)
Sometimes	5 (5%)	8 (12%)	7 (12%)	31 (27%)
Tries to	10 (10%)	7 (10%)	26 (43%)	16 (14%)
Never	72 (74%)	34 (49%)	19 (32%)	6 (5%)
I do not know				2 (2%)
Question: Has any member of the dental team ever given you advice on toothbrushing for your child?				
Yes	47 (48%)	36 (52%)	8 (13%)	8 (7%)
No	50 (52%)	33 (48%)	52 (87%)	107 (93%)

toothbrushing advice given to the children in each of these groups.

Slightly more children ( $n = 343$ ) were observed brushing than for whom questionnaires were completed. Of these children, four were reported not to use fluoride toothpaste and 23 lost toothpaste during brushing which could not be recovered. Complete samples were therefore collected and analysed for a total of 316 children: 85 Dutch children aged between 1.5 and 2.5, 59 Dutch children aged between 2.5 and 3.5, 54 Irish children aged between 1.5 and 2.5 and 118 Irish children aged between 2.5 and 3.5.

For the 1.5- to 2.5-year-old Dutch children the proportion of fluoride that was retained on the toothbrush was, on average,  $22.7 \pm 16.1\%$  (Table 2).

None of the children in this age group were reported to spit only. Only nine out of the 85 (11%) were observed to spit and rinse their mouth during or after tooth brushing. For those children who rinsed and spat ( $n = 9$ ), the proportion of fluoride that was recovered in the expectorate was  $16.5 \pm 15.8\%$  of the amount of fluoride that was dispensed. In total (in the toothbrush and expectorate)  $39.8 \pm 16.8\%$  of the fluoride was recovered from these children.

In the younger age group in the city of Cork, on average, approximately  $17.4 \pm 16.8\%$  of the fluoride that had been dispensed was retained on the toothbrush. Seventeen out of the 54 children (31%) were observed to only spit whereas another 17 (31%) were observed to spit and rinse during brushing (Table 3).

Table 2. Toothbrushing habits and dentifrice fluoride recovery for 1.5–2.5-year-old Dutch children

(F <sup>-</sup> ) in Tp <sup>a</sup> (ppm)		Spit/ rinse	No. of children	Toothpaste used (g)	Fluoride used <sup>b</sup> (µg)	Percentage fluoride recovered from:			
A	B					Tooth- brush	Spit only	Rinse and spit	Toothbrush, rinse and spit
250	220 (22)	No	45	0.38 (0.28)	85.2 (67.2)	22.5 (17.3)			
250	229 (26)	Spit Both	0 5	0.36 (0.25)	86.0 (66.4)	25.9 (10.9)	12.6 (15.1)	38.4 (12.9)	
500	432 (29)	No	27	0.28 (0.14)	122.7 (64.0)	23.6 (15.4)			
500	442 (0)	Spit Both	0 2	0.25 (0.18)	112.7 (78.1)	25.6 (0.6)	20.1 (9.7)	45.6 (10.3)	
≥1000	1357 (29)	No	4	0.19 (0.12)	249.7 (162.1)	17.5 (14.0)			
≥1000	1009 (72)	Spit Both	0 2	0.37 (0.31)	362.1 (287.2)	14.8 (4.9)	23.6 (27.8)	38.5 (32.7)	
Mean				0.33 (0.24)	22.7 (16.1)	22.7 (16.1)	16.5 (15.8)	39.8 (16.8)	
				(n = 85)		(n = 85)	(n = 9)	(n = 9)	

Mean values are given with SD in parenthesis.

<sup>a</sup>A, as indicated by the manufacturers; B, mean fluoride concentrations in the toothpastes used as measured in our laboratory.

<sup>b</sup>Calculated from the amount of toothpaste dispensed and the fluoride concentration of the toothpastes actually measured in our laboratory.

Table 3. Toothbrushing habits and dentifrice fluoride recovery for 1.5–2.5-year-old Irish children

(F <sup>-</sup> ) in Tp <sup>a</sup> (ppm)		Spit/ rinse	No. of children	Toothpaste used (g)	Fluoride used <sup>b</sup> (µg)	Percentage fluoride recovered from:			
A	B					Tooth- brush	Spit only	Rinse and spit	Toothbrush, rinse and spit
500	392 (38)	No	12	0.41 (0.34)	159.8 (133.6)	20.3 (22.1)			
500	445 (63)	Spit	5	0.57 (0.36)	265.7 (189.7)	10.2 (13.3)	4.2 (4.1)		14.3 (12.7)
500	389 (38)	Both	9	0.39 (0.14)	152.3 (51.1)	17.4 (13.3)		20.5 (20.3)	37.9 (15.8)
≥1000	1156 (200)	No	8	0.28 (0.23)	305.8 (256.2)	23.1 (17.7)			
≥1000	1108 (151)	Spit	12	0.35 (0.28)	398.8 (317.9)	16.9 (17.4)	8.5 (9.1)		25.4 (17.1)
≥1000	1099 (200)	Both	8	0.24 (0.15)	273.6 (172.8)	12.7 (12.5)		22.2 (21.4)	34.9 (17.5)
Mean				0.36 (0.27)		17.4 (16.8)	7.2 (8.1)	21.3 (20.2)	22.1 (16.4)
				(n = 54)		(n = 54)	(n = 17)	(n = 17)	(n = 17)

Mean values are given with SD in parenthesis.

<sup>a</sup>A, as indicated by the manufacturers; B, mean fluoride concentrations in the toothpastes used as measured in our laboratory.

<sup>b</sup>Calculated from the amount of toothpaste dispensed and the fluoride concentration of the toothpastes actually measured in our laboratory.

When the children only spat 7.2 ± 8.1% of the fluoride that was dispensed was recovered in the expectorate. The percentage of fluoride recovered from both the toothbrush and the expectorate of these children was 22.1 ± 16.4%. When the children rinsed their mouth, 21.3 ± 20.2% of the dispensed fluoride was recovered in the expectorate and the total

amount of fluoride recovered (on toothbrush and in rinse/spit) amounted to 36.5 ± 16.2% of the fluoride originally placed on the brush.

Tables 4 and 5 show details of toothpaste use by the 2.5- to 3.5-year-olds. Sixteen out of the 59 Dutch children (27%) in this age group spat and rinsed their mouths after brushing (Table 4). Four children

Table 4. Toothbrushing habits and dentifrice fluoride recovery for 2.5–3.5-year-old Dutch children

(F <sup>-</sup> ) in Tp <sup>a</sup> (ppm)		Spit/ rinse	No. of children	Toothpaste used (g)	Fluoride used <sup>b</sup> (µg)	Percentage fluoride recovered from:			
A	B					Tooth- brush	Spit only	Rinse and spit	Toothbrush, rinse and spit
250	221 (19)	No	19	0.37 (0.27)	82.4 (62.8)	24.9 (16.4)			
250	223 (29)	Spit	3	0.57 (0.31)	133.6 (91.0)	11.8 (1.7)	8.6 (8.4)		20.3 (6.9)
250	224 (24)	Both	4	0.40 (0.37)	95.3 (97.9)	12.3 (3.1)		7.1 (8.4)	19.5 (10.6)
500	436 (25)	No	18	0.46 (0.29)	203.8 (130.4)	20.2 (17.8)			
500	437	Spit	1	0.2	87.4	47.8	8.9		56.1
500	438 (31)	Both	11	0.44 (0.20)	189.7 (80.8)	35.4 (18.3)		20.3 (18.1)	55.7 (16.8)
≥1000	1343 (0)	No	2	0.2 (0.16)	262.1 (218.9)	27.3 (21.3)			
≥1000		Spit	0						
≥1000	1004	Both	1	0.2	200.8	13.2		41.6	54.8
Mean				0.41 (0.27)		24.3 (17.3)	8.7 (6.9)	18.3 (17.5)	29.3 (18.8)
				(n = 59)		(n = 59)	(n = 4)	(n = 16)	(n = 4)

Mean values are given with SD in parenthesis.

<sup>a</sup>A, as indicated by the manufacturers; B, mean fluoride concentrations in the toothpastes used as measured in our laboratory.

<sup>b</sup>Calculated from the amount of toothpaste dispensed and the fluoride concentration of the toothpastes actually measured in our laboratory.

Table 5. Toothbrushing habits and dentifrice fluoride recovery for 2.5–3.5-year-old Irish children

(F <sup>-</sup> ) in Tp <sup>a</sup> (ppm)		Spit/ rinse	No. of children	Toothpaste used (g)	Fluoride used <sup>b</sup> (μg)	Percentage fluoride recovered from:			
A	B					Tooth- brush	Spit only	Rinse and spit	Toothbrush, rinse and spit
500	435 (46)	No	9	0.46 (0.29)	196.4 (128.5)				
500	430 (53)	Spit	8	0.27 (0.14)	121.8 (65.5)	26.0 (13.2)	22.2 (20.8)		48.2 (19.4)
500	420 (52)	Both	47	0.43 (0.22)	178.8 (92.4)	22.1 (17.1)		28.6 (23.3)	50.7 (24.3)
≥1000	1110 (205)	No	9	0.41 (0.22)	442.6 (230.3)	36.9 (25.1)			
≥1000	1152 (168)	Spit	9	0.31 (0.13)	343.3 (133.3)	28.5 (13.1)	12.9 (12.7)		41.5 (19.7)
≥1000	1148 (185)	Both	36	0.45 (0.32)	527.5 (385.2)	23.8 (18.6)		33.3 (23.1)	57.0 (20.7)
Mean				0.42 (0.27)		23.9 (17.8)	17.3 (17.1)	30.6 (23.2)	44.6 (19.2)
				(n = 118)		(n = 118)	(n = 17)	(n = 83)	(n = 17)

Mean values are given with SD in parenthesis.

<sup>a</sup>A, as indicated by the manufacturers; B, mean fluoride concentrations in the toothpastes used as measured in our laboratory.

<sup>b</sup>Calculated from the amount of toothpaste dispensed and the fluoride concentration of the toothpastes actually measured in our laboratory.

(7%) spat only. An average of  $18.3 \pm 17.5\%$  of the proportion of fluoride dispensed was recovered in the expectorate from those children who were observed to both rinse and spit, and  $8.7 \pm 6.9\%$  for the children that spat only. The toothbrush retained  $24.3 \pm 17.3\%$  of the fluoride dispensed, making the total percentage of recovered fluoride  $46.6 \pm 21.7\%$  and  $29.3 \pm 18.8\%$  for the children who spat and rinsed and the children who spat only, respectively.

The majority, 83 out of the 118 (70%), of the older Irish children spat and rinsed their mouth during or after brushing (Table 5). For these children an average of  $30.6 \pm 23.2\%$  of the fluoride that had been dispensed on the brush was recovered in the expectorate. Another 14% of the children, 17 out of 118, spat out only during or after toothbrushing. For these children an average of  $17.3 \pm 17.1\%$  of the dispensed fluoride was recovered in the expectorate. The percentage of fluoride that was retained on the brush averaged  $23.9 \pm 17.8\%$ . For the children that spat and rinsed their mouth after brushing, an average of  $53.4 \pm 22.9\%$  of the fluoride that had been dispensed was totally recovered, and for the children that spat only  $44.6 \pm 19.2\%$ .

Statistical analysis showed that the total proportion of recovered fluoride did not depend on nationality, but was significantly higher in the older age group ( $25.2 \pm 17.6\%$  versus  $41.5 \pm 25.1\%$ ), and depended significantly on the spitting and rinsing habits (Tables 2–5). For those children who did not spit or rinse on average  $22.8 \pm 18.1\%$  of the

dispensed fluoride was recovered, for those children who only spat  $31.7 \pm 19.3\%$  and for the children who spat and rinsed  $49.3 \pm 22.3\%$ .

No statistically significant relationship was found between the percentage of fluoride retained on the brush and the amount of toothpaste dispensed. The percentage of fluoride retained on the brush did not depend on the brand or type of toothpaste or toothbrush. In the Netherlands, 25 different types of toothpaste and 19 different types of toothbrushes were used, whereas in Ireland the corresponding values were 40 and 24, respectively.

The proportion of fluoride retained on the toothbrush did not depend significantly on the spitting and rinsing habits of the children and varied from  $20.6 \pm 15.7\%$  for the children who only spat to  $22.6 \pm 16.9\%$  for the children who spat and rinsed and  $22.8 \pm 18.1\%$  for the children who did not spit or rinse at all.

It was possible to calculate the maximum ingested amount of fluoride per kg of body weight for all children in this study had they not rinsed and/or spat during or after toothbrushing. This amount was calculated by dividing the difference between the amount of fluoride dispensed and the amount of fluoride retained on the brush by kg body weight. For the calculations, the fluoride concentrations of the toothpastes as measured in our laboratory were used and not the concentrations that were given by the manufacturers. On average, there was approximately a 12% difference between these two values

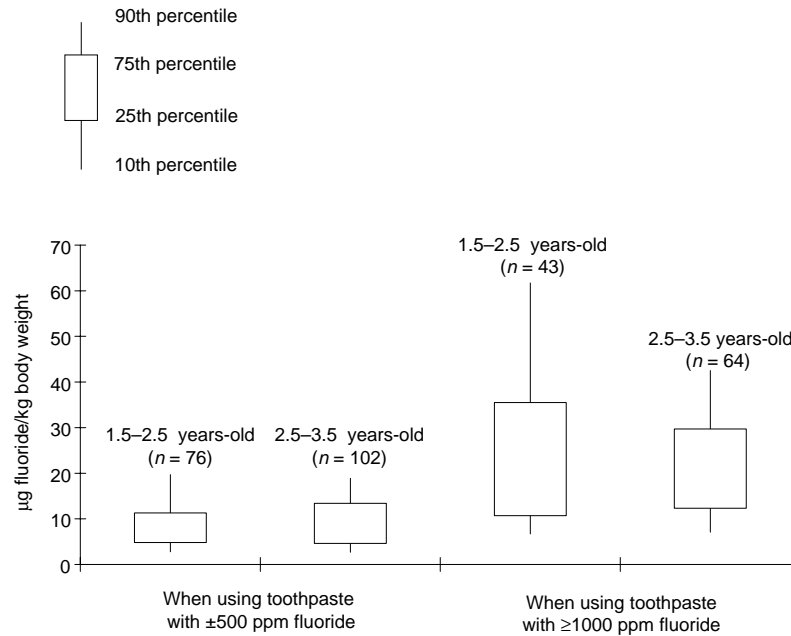


Fig. 1. The maximum ingested amount of fluoride per kg body weight if the children did not rinse or spit at all.

(Tables 2–5). The amount of toothpaste dispensed (g) was statistically significantly different in the two age groups ( $0.35 \pm 0.25$  g and  $0.44 \pm 0.31$  g of toothpaste for the younger and older age group, respectively), but was not related to fluoride concentration in the paste nor to the nationality of the children. Since the proportion of fluoride retained in the toothbrush was also not related to nationality, the results for Dutch and Irish children have been combined. As in the tables the calculations have been based on the amount of toothpaste dispensed and the fluoride concentration of the toothpastes as actually measured in our laboratory. Figure 1 displays maximum ingestible amount of fluoride per kg body weight for the Dutch and Irish children who used a 500 or  $\geq 1000$  ppm F toothpaste had they not rinsed or spat. The 10th, 25th, 75th and 90th percentiles are given. The 250-ppm F toothpastes are not considered, because these pastes are no longer available on the market. For three of the young (4%) and three of the older (3%) children using fluoride toothpaste with 500 ppm F the maximum ingestible amount of fluoride exceeded  $36 \mu\text{g}$  fluoride per kg body weight, above which may increase plasma fluoride to levels that might induce fluorosis (see Discussion). These six children dispensed  $\geq 1$  g of toothpaste on the brush (the group average was  $0.35 \pm 0.25$  g). When using a toothpaste with  $\geq 1000$  ppm (without rinsing or spitting), the maximum ingestible amount of fluoride exceeded  $36 \mu\text{g}$  fluoride per kg body weight for approximately 25% of the younger children and over 10% of the older children. These younger

children dispensed twice as much toothpaste on their brush as the average amount ( $0.8 \pm 0.18$  versus  $0.35 \pm 0.25$  g). This subgroup of the older children dispensed  $0.64 \pm 0.37$  g of toothpaste, while the average amount of toothpaste dispensed in the total group of the older children was  $0.44 \pm 0.31$  g.

## Discussion

The concentration of fluoride in the toothpaste used by the children in the Netherlands differed from that used in Ireland. In the Netherlands, where the water fluoride concentration is between 0.10 and 0.13 ppm, children under the age of 5 years are advised to use toddlers' toothpaste. Before October 1998, toddlers' toothpastes contained 250 ppm fluoride. However, since then, all toothpaste manufacturers have increased the fluoride concentration in toddlers' toothpastes to 500 ppm (11). October 1998 was about the mid-point of our investigation period. The subdivision in the Dutch data in a group of children using 250 ppm F and a group using 500 ppm F probably reflects the availability of these toothpastes. The use of toothpastes containing  $\geq 1000$  ppm fluoride is not advised in the Netherlands for children of this age group. In Ireland, where the water is fluoridated to between 0.8 and 1.0 ppm F, there is no particular recommendation regarding the fluoride concentration in the toothpastes for the children in this age group.

In the Netherlands, only 11% of children (nine out of 85) in the 1.5–2.5-year age group rinsed and

expectorated during or after toothbrushing (Table 2). In the older age group 7% (four out of 59) of the children spat only while 27% of the children (16 out of 59) rinsed and spat during or after toothbrushing (Table 4). The amount of fluoride cleared from the mouth by this rinsing and spitting was approximately the same as the amount that was retained on the toothbrush. In Ireland in the younger age group approximately 31% of the children spat only. Little additional fluoride (approximately 7%) was cleared from the mouth by this procedure. Another 31% of the children rinsed and expectorated during and/or after brushing. By this procedure a little more fluoride was cleared from the mouth than was retained on the toothbrush, 21% versus 17%, respectively. In the older age group almost all children (70%) rinsed and expectorated during or after brushing, clearing a little more fluoride from the mouth than was retained on the toothbrush, 31% versus 24%.

The difference in rinsing behaviour between the Dutch and Irish children is remarkable. It is not believed to be a bias of this study, as the numbers of children that rinsed their mouth and expectorated or expectorated only was in fair agreement with the number of parents who reported in the questionnaire that their child normally spat out during or after tooth brushing.

When asked, 48–52% of the Dutch parents indicated that they had received advice on toothbrushing from their own dentist or dental hygienist. It is not known whether the advice they received included instructions to encourage their child to expectorate and avoid swallowing toothpaste. In contrast, in Ireland only 7–13% of the parents indicated that they had received advice on toothbrushing from a dental team. In Ireland rinsing during brushing appears to be a cultural habit that parents encourage their children to do because most of the children rinse and spit without having received advice from a dental professional.

The aim of this study was to measure the amount of fluoride retained on the toothbrush and recovered from any expectorate after brushing and, in so doing, to determine the importance of rinsing and spitting on fluoride ingestion from toothpaste. The results indicate that the amount of fluoride recovered, and hence the amount of fluoride ingested from toothpaste, was significantly related to rinsing and spitting habits. Enamel fluorosis may develop as a result of excessive systemic intake of fluoride during enamel formation. For the aesthetically important teeth the first years of life are the most

important ones with the highest risk period reported to be between 22 and 48 months of age (12–15). The evidence indicating that use of fluoride toothpaste is a risk factor for enamel fluorosis is inconclusive (16–25). The range of 0.05–0.07 mg F/kg body weight/day (26, 27) is regarded as the level of intake beyond which unacceptable dental fluorosis may occur, although some authors refer to this level as the optimal range for fluoride intake in children (28–30). It is important, however, to consider how fluoride is ingested over time. In contrast to fluoride ingested from drinking water and diet, fluoride from toothpaste will be ingested in one or two doses a day. Based on results from an animal study, Angmar-Månsson and Whitford (31) concluded that under these conditions fluoride may only constitute a risk for fluorosis when high peak levels of plasma fluoride are reached. They concluded that, when plasma levels are considered, the rat and human appear to develop enamel fluorosis at very nearly the same fluoride concentration (31). Daily peak levels of 0.19 ppm F in the plasma of rats induced visible fluorosis, while peak levels of 0.1 ppm F twice daily did not (31). Later, Ekstrand et al. (32) showed that the plasma fluoride did not reach 0.1 ppm when children, 3–4 years of age, swallowed 36 µg fluoride per kg body weight all at once from fluoride toothpaste, which therefore can be regarded as a safe ingestible dose during brushing when children are brushing not more than twice a day. Furthermore, it is clear that plasma F peaks resulting from ingested fluoride are very sensitive to the presence of previously consumed foods or drinks (33).

In our study we calculated the amount of fluoride that would be retained when children did not rinse. This may still be an overestimation of the amount of fluoride that children could swallow because some of the fluoride is retained in the oral soft tissues and teeth and probably never swallowed. Even if such fluoride was swallowed later on this would only contribute to the overall body burden but not to any potentially harmful plasma peak. The results of our study suggest that children using a toothpaste with up to 500 ppm F may ingest >36 µg F/kg body weight, when they dispense ≥1 g of toothpaste and do not rinse after brushing (Fig. 1). When using toothpaste with ≥1000 ppm without rinsing or spitting the maximum ingestible amount of fluoride exceeds 36 µg F/kg body weight for approximately 25% of the younger children and over 10% of the older children. These children dispensed more fluoride on the brush than the average. Therefore the recommendations that younger children use a small

amount of toothpaste (<0.5 g) and that children using toothpaste with  $\geq 1000$  ppm rinse their mouth after brushing the teeth continue to be valid.

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