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Fluoride exposure from ingested toothpaste in 4–5-year-old Malaysian children

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Abstract – *Objective:* The aim of this study was to assess (by direct determination) the fluoride (F) exposure from ingested toothpaste among 4–5-year-old Malaysian children. *Methods:* This was part of a larger study to determine fluorosis status and F exposures. A total of 1343 10–11-year-old subjects were sampled by two-stage systematic random sampling for assessment of fluorosis. Two hundred 4–5-year-old siblings of these index subjects were subsampled for determination of F exposures from ingested toothpastes and other sources. Estimations of F ingested from toothpaste (FI) was made by the method of difference between 'F in toothpaste taken for use' and the 'F in toothpaste used but not swallowed', by the duplicate technique under normal home conditions. F ions were determined with the combination selective ion electrode. *Results:* The subjects ingested 32.9% of the toothpaste placed on the brush. Fluoride exposure from ingested toothpaste was highly variable and the mean was 426.9 ± 505.5 μg (SEM 38.9)/48 h, or 213.5 μg/day and 131.9 μg per brushing. *Conclusions:* The amount of ingested fluoride (FI) per brushing in this study was the lowest of all studies reporting this parameter and was within the pea-size range of 125–250 μg. Because of the highly statistically significant correlations between the FI from toothpaste and the amount of toothpaste dispensed (Pearson's correlation coefficient 0.647, $P = 0.000$), parents should assume responsibility for placement of toothpaste and limit the amount of toothpaste used.

Key words: fluoride exposure; ingested toothpaste; Malaysia; 4–5 years

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Water, although often the most common source of fluoride (F), is however no longer the only significant source of F. Literature reports that fluorosis caused by water fluoridation (40%) as being less than that attributable to other F sources (60%) (1). By the 1990s, F toothpaste accounted for ≥90% of the toothpaste market in most economically developed countries (2), and accidental or intentional ingestion of fluoridated toothpaste especially in children has become a potentially important risk factor for excessive F exposure.

Fluoride from toothpaste has been shown to be readily bioavailable (3, 4). The conclusion thus was ingestion of F (FI) from the toothpaste should be minimized. Limiting the amount of paste used can reduce fluoride ingestion. Ericson and Forsman (5) first recommended a pea-size amount. Rock (6) however felt that pea-size amounts may be too much and that only smear amounts should be used.

Alternatively, low-F toothpaste should be used. However, at F levels <1000 ppm, efficacy is yet to be established fully (7). Holt et al. (8), in their study with low (550 ppm) versus standard amounts (1050 ppm) given to preschool subjects of age 2 years at the start of a 3-year trial ($n = 1523$), reported small differences in real terms. Fluorosis, using the Thylstrup-Fejerskov (TF) index (both child and tooth prevalence), and diffuse defects scored with the Developmental defects of enamel (DDE) index, was significantly lower in the children given the test paste, but there were no significant differences in prevalence of caries in either primary or permanent teeth, although a trend towards higher prevalence of disease was seen with the test paste. Forsman (9) also failed to demonstrate any advantage from using a 250-ppm F toothpaste as did Mitropoulos et al. (10). Koch et al. (11) claimed that 500 ppm F was equivalent to 2000 ppm NaF.

It is therefore timely to investigate FI from toothpaste and any alterations necessary to the policies concerning control of dental products as well as dental health behaviour programmes.

To date, there have been only a few Malaysian studies (12, 3) on the extent of usage of F toothpaste in children. These, however, were limited attempts. Amdah and Jaafar (13) investigated tooth-brushing behaviour, including toothpaste usage, in preschool children. In that study, however, only the amount of toothpaste used in a small sample limited to Malay preschoolers in the Banting district and not F toothpaste ingestion was determined. No studies have ever been conducted to determine F toothpaste ingestion in Malaysian children at the time of enamel formation.

The objective of this study was to assess the exposure to F from ingested toothpaste (by direct determination) among 4–5-year-old Malaysian children during which time, active enamel formation takes place.

Materials and methods

This was part of a larger study to determine fluorosis status and F exposure. The study was conducted in Selangor, a fluoridated area centrally located on the west coast of peninsular Malaysia where the prevalence of enamel defects among adolescents was 69.9% with 95.5% of the defects being diffuse opacities (14). In the main study, 1343 10–11-year-old (index) subjects were examined. Of these, 342 subjects had a 4–5-year-old sibling. The younger siblings were proxies in whom F exposure from the various sources was measured. From the 342 4–5-year-old siblings, 200 were subsampled for determination of F exposures including total F exposure via 24-h urine excretions, and F exposures from drinking water and ingested toothpastes. This paper is concerned with the F exposures from ingested toothpaste in the 4–5-year olds.

For determinations of F exposure from ingested toothpaste, pairs of identical toothbrushes were given to the 4–5-year-old subjects. Instructions were given to the parent or the child himself/herself depending on the prevailing practice, to dispense the amount of toothpaste, as would normally be used, each time the teeth is brushed, onto both the toothbrushes in the pair. One toothbrush (with the toothpaste dispensed) was placed back into the packet and kept for collection and subsequent F determination. The other was used after which, the used toothbrush (with residual toothpaste), was placed into a separate plastic bag labelled 'USED' and kept for subsequent collection and F determination. Instructions were also given to the children to collect rinses in plastic receptacles. Enough toothbrushes and receptacles were given to the children for the two study days. Samples of water sources used for toothbrushing were obtained in order to determine the F content of water used in rinsing. The rinses were collected in plastic receptacles for determining the volume of water used.

All F determinations were made with a direct concentration read-out specific ion meter EDT DR359 (EDTdirectION Ltd., Dover, UK) used in conjunction with a combination ion-selective electrode QSE333. Double de-ionized water was used to prepare all solutions and samples, and for any rinsing and/or washing in laboratory analysis. TISAB (part number 30333) was added to dilute standards and samples before measurement. The performance of the electrode was checked by first confirming that the mV/decade slope was within the theoretical value of 54–60 mV/decade.

Free fluoride ion concentrations in toothpaste was determined by the methodology adapted from the Malaysian Standard Specification for toothpaste (15) of Standards and Industrial Research Institute of Malaysia (SIRIM). Modifications were necessary as SIRIM tested toothpastes in the form of slurries of weighted samples, while in this study, determinations were performed on dispersions of the toothpastes in known volumes of double de-ionized water or rinsings. Recoveries were between 81.0% and 113.8% averaging 88.8% (values were 91.9, 84.7, 89.6, 91.1, 81.0, 82.2, 88.3, 87.8, 113.8, 90.2, 86.2, 84.1 and 82.8%).

From the determinations of F in the dispensed toothpaste, the residual toothpaste, the rinses and the sample of water used for rinsing, the amount of fluoride from ingested toothpaste was determined:

$$F_I = F_D - F_R - (F_{EXP} - F_{RINSE\ WATER}),$$

where F_I is F from ingested toothpaste, F_D the F in toothpaste dispensed, F_R the F in residual toothpaste on the brush, F_{EXP} the F in expectorant and $F_{RINSE\ WATER}$ the F in water used for rinsing.

Data were stored and analysed with the SPSSPC+ statistical package. The *t*-test and ANOVA were used to compare differences in mean values of variables between two and more groups. The Levene's test was used to determine homogeneity of variances, and the *P*-values corresponding to the assumed equality or nonequality of the variances were then determined. Level of significance was set at $\alpha = 0.05$.

Results

Samples of rinses were returned from 182 of the 200 subjects who were subsampled; dispensed toothpaste and residual toothpaste samples were obtained from 180 subjects; 174 subjects returned dispensed toothpaste, residual toothpaste and rinses. Of these, however, either because of the differences between dispensed amounts and residual amounts being smaller than the amount of fluoride expectorated into the rinses, or the dispensed amount being smaller than residual amounts, only 167 specimens were analysable for the amount of F from ingested toothpaste.

The F_{EXP}, $F_{RINSE\ WATER}$, F_{EXP} (corrected for F for water used), FI per brushing and the proportion of toothpaste dispensed that was ingested were derived with the following formulae for each case individually:

(i) F_{EXP} = Rinse volume × Rinse [F]
(ii) $F_{RINSEWATER}$ = Rinse volume × [F] water source used for toothbrushing
(iii) F_{EXP} (corrected for F for water used) = $F_{EXP} - F_{RINSE\ WATER}$
(iv) FI per brushing = FI per 48 h/Number of times brushed in 48 h, and
(v) Proportion of toothpaste ingested = (FI per 48 h/F in toothpaste dispensed in 48 h) × 100%

The values of the parameters relevant for computation of FI over the two study days, per day and per brushing, are tabulated in Table 1.

Fluoride exposure from ingested toothpaste was highly variable as can be seen from the mean, median, standard deviation and standard error values in Table 1. There were no significant differences in mean fluoride exposures from this source between gender and racial groups (male 430.0 μg, female 434.7 μg, $P = 0.9$; Malay 427.6 μg, Chinese 277.3 μg, Indian 648.1 μg, others 680.4 μg, $P = 0.07$).

Discussion

The picture of exposure ideally need be captured from 4–5 months to 7 years. However, as the study involved determination of total F exposures from 24-h urine samples and because collection of these samples in individuals of ≤3 years would be difficult, the study was limited to 4–5-year olds. Other limitations of the study identified included biases.

Selection biases that could occur included bias because of the subsampling carried out based on the subjects having a younger sibling of 4–5 years old. There were however no significant differences between the subjects with or without siblings except that subjects with siblings tended to be from larger families and more often of Malay and Indian ethnic group than Chinese. However, this is unlikely to affect the results as there were no significant racial differences in F intake from the different sources for the three main ethnic groups.

Non-response bias, i.e. bias because of the possibility that subjects who had responded and

Table 1. Fluoride from ingested dentifrice in 4–5-year old subjects[a]

Values over 48 h	Mean	Median	SD	SEM
Toothpaste				
F in toothpaste dispensed (μg)	1296.6	1057.7	974.8	72.6
F in residual toothpaste (μg)	444.8	315.0	399.8	29.8
Rinses				
Rinse volumes (ml)	204.6	140.5	225.5	16.71
Rinse [F] (ppm)	6.33	2.90	1.12	0.8
F in rinses (μg)	728.3	472.3	1444.5	107.1
F rinse water (μg)	114.3	70.4	143.2	
F expectorated (corrected for F from water used) (μg)	499.8	368.0	520.7	22.00
FI per 48 h	426.9	279.6	505.5	38.9
FI per day	213.5	139.8	252.8	19.5
FI per brushing	131.9	84.8	151.7	11.7

[a]Complete analysable data set ($n = 167$).

provided complete sample sets had parents who were more highly motivated or differed in some way from those of nonresponders could not be ruled out. Parents who were more motivated would probably be more involved in the oral hygiene habits of their children and these might have an effect on the amount of F exposure from this source. However, there were no obvious differences in sociodemographic characteristics between subjects who responded and those who did not. Ascertainment or information bias in the measurement of exposure/outcome was possible as respondents may be influenced by being under study (Hawthorne effect).

Another limitation was a consequence of the funding made available to the study. The fluoride measurements were made from day to day for 2 days with measurements pooled over 48-h periods. A slightly longer period of collection of 5 days of the biological specimens may give a better reflection of actual means of fluoride exposures as well as insight into day-to-day variations. Moreover, if not for financial constraints, all 342 subjects with siblings could have been selected for biochemical determinations so that the final sample size would be bigger.

The ion-specific electrode used to ascertain the fluoride concentrations of all specimens collected determined soluble F present as free ions. This limitation was deemed acceptable as in dentistry and medicine it is the ionic F that are of importance (16, 17).

The duplicate technique was applied in this study. Any spillage in amount taken would result in an underestimation of the amount ingested, whereas any spillage of amount used but not ingested would result in overestimation of amount ingested. Failure to dispense exactly the same amount of toothpaste representative of the amount normally used on both toothbrushes would render the calculated difference (the amount deemed ingested) invalid. A worse scenario is when the amount on the brush that was in fact used, had more toothpaste dispensed on it than on the duplicate which was not used; negative values resulted as with some samples. The reverse circumstances could also have occurred; i.e. the brush that was used having less toothpaste than the measured duplicate brush. These would not be so readily identifiable for exclusion and would result in an overestimation of the amount ingested. Had all 174 data sets been included in this study, lower mean (386.8 μg) and median (265.3 μg) values were obtained. If the amounts of paste were correctly duplicated, similar problems with calculation could arise because of non-uniformity of F content through the tube of paste. This problem could have been averted by taking the weight of toothpaste used and multiplying with the purported F concentration of the tube of toothpaste. This method would give better estimates of F from toothpaste ingested on a long-term (chronic) basis. However, not all brands of toothpaste are labelled with the F content. Moreover, inputting this 'long-term' value might render the back calculation of dietary F from values of F from other sources (over the two study days) inaccurate.

The method employed took into account toothpaste ingested during the actual acts of tooth brushing. Any toothpaste that is deliberately swallowed/eaten not during tooth brushing would not be accounted for. However, subjects were allowed to brush their teeth, rinse etc. as they normally do in their own homes without being directly observed by the researcher. This was an advantage as subjects may deviate from their normal brushing habits if observed. However, on-site correction of errors because of noncompliance and poor understanding of instructions could not be given. The findings of this study were therefore interpreted and discussed within these limitations.

There are no known Malaysian studies with actual quantification of F from ingested toothpaste. Many studies and reviews of ingestion of F from toothpaste were estimates based on parents' response to toothpaste used by selecting from pictures depicting children's toothbrushes with different quantities of toothpaste on them (18–22) rather than by direct measurements. Brunn and Thylstrup (23) weighed the amount of paste used, assumed the toothpastes to be of 1000 ppm F, and then estimated the ingestions on the assumption that 3- and 7-year olds ingested 30% and 15% (5, 24–26) of the toothpaste used respectively. In studies on ingested toothpaste with direct determinations, mainly the method of difference between the amounts taken and amount used but not ingested have been employed to calculate the amount ingested. The substances assayed, however, have been varied including tracers (25) or soluble ingredients and markers such as calcium carbonate (27) and abrasive particles (24). Excretion markers were also used in the past (28–30). Hargreaves et al. (24) had commented that the use of excretory markers will tend to underestimate ingestion if markers are lost/not recovered, whilst the more common principle of difference employed will overestimate ingestion as any accidental loss will be recorded as ingestion.

The actual F content of the toothpaste had been determined in this study. This was also determined in several other studies (31–36). In this investigation, there were some negative values, which may cast doubts on the reliability/representativeness of the specimens. This, however, was not unique to this study. Baxter (27), in his study, also had some cases of negative values obtained for ingestion. As in Baxter's study (27), these values were mostly small and within the bounds of experimental error for the analytical method used. In his study, Baxter (27) had treated these negative findings as zero ingestion in calculation of mean values as in this study.

Some studies introduced artificial situations; Ericson and Forsman (5) and Salama et al. (37) measured the amount of toothpaste to be used by each; Naccache et al. (33) provided the toothpaste for use; Baxter (27) carried out tooth brushing in a mobile dental unit. Barnhart (25) attempted simulating home conditions and observed subjects unobtrusively through a one-way mirror. In this study, the subjects were reminded to do what was normally done under home conditions and hence the results were as natural as possible.

Children aged 3–5 years have been found to swallow up to 0.25–0.5 g of toothpaste, the equivalence of 0.25–0.5 mg F (24–25, 27–30) assuming use of 1000-ppm toothpaste. Young children who do not have complete mastery over their swallowing reflex may ingest 25–65% of the toothpaste placed on the brush (5, 19, 33, 38). Ripa (19), in his review, estimated that the average daily amount of fluoride ingested by preschool children brushing twice daily with toothpaste of standard strength (1000–1100 ppm F) was 0.27 mg. On the basis of a pea-size being 0.25 g and assuming the use of 500- or 1000-ppm toothpaste, the amount of F in a pea-size of paste would be 125–250 μg. The mean F content in toothpaste dispensed in this study was 1296.6 μg per 48 h, 648.3 μg per day, 400.9 μg per brushing exceeding the pea-size amount. Haftenberger et al. (39) reported that 3–6-year-old children swallowed up to 273.9 ± 175 μg F/day. Baxter (27) studying 85 5–16-year-old children found the mean weight of toothpaste ingested to be 0.19 g; for the comparable subjects in the 5–6-year age group, the mean weight ingested was 0.27 g. Seventy per cent of the subjects (24) swallowed ≤0.5 g, with the worst performer ingesting 1.16 g per brushing.

In this study, F ingested from toothpaste was significantly correlated with the following:

(i) frequency of brushing (Pearson's correlation coefficient 0.186, $P = 0.016$);
(ii) frequency of rinsing (Pearson's correlation of coefficient 0.177, $P = 0.024$); and
(iii) amount of toothpaste dispensed (Pearson's correlation coefficient 0.647, $P = 0.000$).

The findings of several studies on ingestion of toothpaste are tabulated in Table 2. In the present study, the proportion of dispensed toothpaste that was ingested was 32.9%. This finding was comparable with that of the 2–4-year olds in Barnhart's study (25), the 5-year olds reported in Canada (31), Ericson and Forsman's (5) 4–5-year-old subjects, those of Hargreaves (24) and Salama et al. (37) and the 3–5-year olds in Quebec (32).

The absolute quantities of F ingested per day in this study were comparable with that of Guha-Chowdhury et al. (34), Villa et al. (36) and Haftenberger et al. (39). Findings were however lower when compared with those of Simard et al. (31), Naccache et al. (33), and Rojas-Sanchez et al. (35). The amount of F ingested per brushing in this study was the lowest of all studies reporting this parameter.

Differences with the results of Simard et al. (31) were probably because of differences in supervision during tooth brushing (nearly all children brushed their teeth by themselves as opposed to 86.3% being supervised in this study); higher frequencies of brushing (71.4% brushed twice, 23.8% thrice and only 4.8% once or less than twice, when compared with 52.1%, 1.2% and 46.7%, respectively, in this study). There were also differences in rinsing habits (78% and 98.7%) in the study of Simard et al. (31) and in this study respectively.

The subjects in Naccache's study (34) used 0.24% NaF (1000 ppm F) paste whereas in this study 50.9% used normal F toothpaste and 49.1% used low-F formulations. The study by Rojas-Sanchez et al. (35) had been on a largely younger cohort and ingestion of toothpaste is known to increase with decreasing age.

Ingestion reportedly decreases with rinsing (27) and most children do not expectorate or rinse (21, 33). However, in this study, an overwhelming majority (98.7%) of the subjects do. Baxter (27) has however found rinsing to be ineffective in 5–6-year olds. In this study, interestingly, a paradox is found – the amount of F from ingested toothpaste is positively correlated with the frequency of rinsing (Pearson's correlation coefficient 0.177, $P = 0.016$). This was perhaps because of subjects who could not

Table 2. Comparison of dentifrice usage, ingestion and fluoride intake from swallowed dentifrices

Study (reference number), n, age (years)	Amount used (μg)	Amount ingested [μg (%)]	F dispensed per brushing (μg)	F ingested per brushing (μg)	F ingested/day (μg)
Ericson and Forsman, 1969 (5), 4–5, n = not available	390–510	130 (26.1–33.2)			
Hargreaves et al., 1972 (24), 3–6, $n = 44$	1380 ± 776	380 ± 0.358 (27.7)			
Barnhart et al., 1974 (25), 2–35					
Age 2–4; $n = 62$	860	300 (34.9)			
Age 5–7; $n = 56$	940	130 (13.9)			
Glass et al., 1975 (26); US, 8–10; $n = 67$	980–1120	117–0.123 (10–12)			
Baxter, 1980 (27), London, 5–16 years, $n = 85$	990 ± 40	190 ± 0.02 (18.0)			
Age 5–6, $n = 8$		270			
Bruun and Thylstrup 1988 (23), Denmark, 3–16, 179					
Age 3 years, $n = 63$	1100 ± 680	[a]			
Age 7 years, $n = 31$	1500 ± 980				
Salama et al., 1989 (37), 3–10 years, $n = 19$	1000 (given)	360 ± 50 (36)			
Simard et al., 1989 (31), Canada, 2–5, $n = 23$					
Age:2–3, $n = 5$	464 ± 190	278 ± 130 (59.4)		304 ± 150	–
Age 4: $n = 9$	783 ± 280	390 ± 250 (48.1)		429 ± 270	–
Age 5: $n = 9$	651 ± 340	221 ± 120 (34.0)		243 ± 130	–
All	622 ± 300	299 ± 190 (48.1)		329 ± 200	730 ± 460
Naccache et al., 1990 (32), Quebec, 3–5, $n = 48$	416–545	135–152 (31.3–40.0)			
Naccache et al., 1992 (33), Quebec					
Age = 4; $n = 81$	446 ± 269	–(49.0)	–	241 ± 184	
Age = 5, $n = 77$	516 ± 366	–(42.0)	–	227 ± 174	
Guha-Chowdhury et al., 1996 (34), NZ, 3–4 years $n = 66$					
	130–1480[c]			340	0–1290 (0–87%)[c]
	580 ± 290[b]			320	230 ± 230[b]
Rojas-Sanchez et al., 1999 (35), $n = 54$, 16–40 months					
San Jan, Puerto Rico, $n = 11$			450 ± 30[a]		548 ± 62[a]
Connersville, Indiana; $n = 14$			450 ± 60[a]		576 ± 86[a]
Indianapolis, Indiana, $n = 29$			430 ± 90[a]		424 ± 73[a]
Villa et al., 2000 (36), 3–5, $n = 20$	370 ± 80	– (43.6 ± 11.5)			254 ± 79
Haftenberger et al., 2001 (39), 3–6, $n = 11$ [F] = 0.5 ppm					273.9 ± 175
This study	Not determined	– (32.9)	400.6 ± 301.2	131.9 ± 151.7	213.5 ± 252.5

[a]SEM, not SD; [b]12 months later when age = 4–5 years; [c]baseline.

prevent their inadvertent swallowing of toothpaste attempting to 'correct' the situation by rinsing more (to no avail!). However, in the absence of other evidence this remains speculative.

Correlation coefficient between the amount used and the mean amount ingested significant at 0.01 level was reported by Hargreaves and Barnhart and their co-workers (24, 25) but not by Baxter (27). In this study, the correlation was even stronger (Pearson's correlation coefficient 0.647, $P = 0.000$). Naccache et al. (32) found that the amount of toothpaste used accounted for 60% of the variation of amounts ingested. Brunn and Thylstrup (23) showed a positive relationship with the diameter of the orifice of the tubes.

Heifetz and Horowitz (1989), as cited in Simard et al. (31) stated that studies show that a large proportion of children start using toothpaste while they are very young, often without the assistance of parents. In the present investigation, the mean age of starting to use toothpaste was 35.3 ± 15.6 months, and 86.3% of subjects were purportedly supervised during tooth brushing. In Canada (31), although most children brushed their teeth by themselves, most parents put the toothpaste on the brush. In their work, Barnhart et al. (25) noted 95% of parents dispensing toothpaste and 40% actually brushed their children's teeth. In the present investigation, 62.2% applied toothpaste and 25.9% brushed their children's teeth. A local study (40) reported a lack of manual dexterity of children of the 6-year-old age group to effectively brush their teeth. Parental assistance thus would assist them to carry out the tooth brushing procedure as well as assert control over the use and ingestion of toothpaste.

Adair et al. (21), in a study to compare use of child versus adult formulations, found that children preferred toothpaste designed especially for them. The mean weight and the time spent on brushing were more with the child formulation when compared with that of the adult (0.689 ± 0.43 g child versus 0.509 ± 0.41 g adult, $P = 0.02$; and 83.56 ± 85.4 s child versus 57.48 ± 39.0 s adult, $P = 0.01$) leading to increased risk factor (weight × time of usage) (58.54 ± 64.8 > 27.43 ± 25.0, $P = 0.001$). Recommendations for lower F formulations to lower the risk of fluorosis therefore need to be balanced against this tendency.

Although many explanations have been suggested for the decline of caries (and the diminishing difference between fluoridated and non-fluoridated areas), that the F toothpaste has contributed to the decline is without doubt (41). It is now widely believed that F toothpaste presents the most convenient means of preventing caries (42).

Conclusions and recommendations

The mean F exposure from this source in this study was 426.9 μg/48 h or 213.5 μg/day and 131.9 μg per brushing. The amount of F ingested per brushing in this study was the lowest of all studies reporting this parameter.

It would seem that the current levels of F in toothpaste do not lead to excessive F exposures in the preschoolers or alternatively, tooth-brushing habits have become more appropriate and there is no need for any downward adjustments in the standards for toothpaste. However, the F exposure was widely variable (the 5th percentile and 95th percentile for amount ingested per day being 0.0 and 1451.8 μg), and a mere switch to a toothpaste with different F content or formulation could easily increase the F exposure from this source by several folds. Hence, the ingestion of toothpaste by young children should be constantly monitored with special attention towards flavoured formulations. Because of the highly statistically significant correlations between the fluorides ingested from toothpaste and the amount of toothpaste dispensed (Pearson's correlation coefficient 0.647, $P = 0.000$), parents should at least assume responsibility for placement of toothpaste and should be reminded to limit the amount of toothpaste used until the child is 6–7 years of age.

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References

1. Lewis DW, Banting DM. Water fluoridation: current effectiveness and dental fluorosis. Community Dent Oral Epidemiol 1994;22:153–8.

2. Burt BA. The changing patterns of systemic fluoride intake. J Dent Res 1992;71(Spec Iss):1228–37.
3. Ekstrand J, Ehrnebo M. Absorption of fluoride from fluoride dentifrices. Caries Res 1980;14:96–102.
4. Ellingsen JE, Ekstrand J. Plasma fluoride levels in man following intake of SnF2 in solution or toothpaste. J Dent Res 1985;64:1250–2.
5. Ericsson Y, Forsman B. Fluoride retained from mouthrinses and dentifrices in pre-school children. Caries Res 1969;3:290–9.
6. Rock WP. Young children and fluoride toothpaste. Br Dent J 1994;177:17–20.
7. Stephen KW. Dentifrices: recent clinical findings and implications for use. Int Dent J 1993;43:549–53.
8. Holt RD, Morris CE, Winter GB, Downer MC. Enamel opacities and dental caries in children who used a low fluoride toothpaste between 2 and 5 years of age. Int Dent J 1994;44:331–41.
9. Forsman B. Studies on the effect of dentifrice with low fluoride content. Community Dent Oral Epidemiol 1974;2:166–75.
10. Mitropoulos CM, Holloway PJ, Davies TG, Worthington HV. Relative efficacy of dentifrices containing 250 or 1000 ppm F in preventing dental caries-report of a 32-month clinical trial. Community Dental Health 1984;1:193–200.
11. Koch G, Petersson LG, Kling E, Kling L. Effect of 250 and 1000 ppm fluoride dentifrice on caries: a three-year clinical study. Swed Dent J 1982;6:233–8.
12. Norhaliza H, Jaafar N. Fluoride toothpaste utilisation behaviour among preschool children according to their mothers. Kuala Lumpur: Department of Community Dentistry, University of Malaya; 2000.
13. Amdah M, Jaafar N. Fluoride toothpaste usage among preschool children. Paper presented at FDI Annual World Dental Congress Kuala Lumpur 27 Sep to 1 October 2001.
14. Oral Health Division, Ministry of Health. National oral health survey of school children 1997 (NOHSS'97). 1998.
15. SIRIM. Malaysian Standard MS527:1986 UDC 665.583 Specification for toothpaste (First Revision). Shah Alam: Standards and Industrial Research Institute of Malaysia; 1986.
16. Whitford GM. The metabolism and toxicity of fluoride. Monographs in oral science, Vol. 13. Basel: Karger; 1989.
17. Ophaug R. Determination of fluorine in biological materials: reaction paper. Adv Dent Res 1994;8:87–91.
18. Beltran ED, Szpunar SM. Fluoride in toothpaste for children: suggestion for change. Pediatric Dent 1988;10:185–91.
19. Ripa LW. A critique of topical fluoride methods (dentifrices, mouthrinses, operator and self-applied gels in an era of decreased caries and increased fluorosis prevalence). J Public Health Dent 1991;51:23–41.
20. Levy SM, Kohout FJ, Kiristy MC, Heilman JR, Wefel JS. Infants' fluoride ingestion from water, supplements and dentifrices. JADA 1995;126:1625–32.
21. Adair SM, Pisciteli WP, McKnight-Hanes C. Comparison of the use of a child and an adult dentifrice by a sample of preschool children. Pediatric Dent 1997;19:99–103.
22. Oral Health Division, Ministry of Health Malaysia. Fluoride enamel opacities in 16-year-old school children. June 2001.
23. Bruun C, Thylstrup A. Dentifrice usage among Danish children. J Dent Res 1988;67:1114–7.
24. Hargreaves JA, Ingram GS, Wagg BJ. A gravimetric study of the ingestion of toothpaste by children. Caries Res 1972;6:237–43.
25. Barnhart WE, Hiller LK, Leonard GJ, Micheals SE. Dentifrice usage and ingestion among four age groups. J Dent Res 1974;53:1317–22.
26. Glass RL, Peterson JK, Zuckerberg DA, Naylor MN. Fluoride ingestion resulting from the use of a monofluorophosphate dentifrice by children. Br Dent J 1975;138:423–6.
27. Baxter PM. Toothpaste ingestion during tooth brushing by school children. Br Dent J 1980;148: 125–8.
28. Hargreaves JA, Ingram GS, Wagg BJ. Excretion studies on the ingestion of a monofluorophosphate toothpaste by children. Caries Res 1970;4:256–68.
29. Hargreaves JA, Ingram GS, Wagg BJ. An extended excretion study on the ingestion of a monofluorephosphate toothpaste by children. Acta Med Hung 1970;27:413–19.
30. Naylor MN, Melville M, Wilson RF, Ingram GS, Wagg BJ. Ingestion of dentifrice by young children: a pilot study using a fecal marker. J Dent Res 1971;50:687.
31. Simard PL, Lachapelle D, Trahan L, Naccache H, Demers M, Brodeur JM. The ingestion of fluoride dentifrice by young children. J Dent Child 1989;56:177–81.
32. Naccache H, Simard PL, Trahan L, Demers M, Lapointe C, Brodeur JM. Variability in the ingestion of toothpaste by preschool children. Caries Res 1990;24:359–63.
33. Naccache H, Simard PL, Trahan L, Brodeur JM, Demers M, Lachapelle D et al. Factors affecting the ingestion of fluoride dentifrice by children. J Public Health Dent 1992;52:222–5.
34. Guha-Chowdhury N, Drummond BK, Smilie AC. Total fluoride intake in children aged 3 to 4 years: a longitudinal study. J Dent Res 1996;75:1451–7.
35. Rojas-Sanchez F, Kelly SA, Drake KM, Eckert GJ, Stookey GK, Dunipace AJ. Fluoride intake from foods, beverages and dentifrices by young children in communities with negligibly and optimally fluoridated water: a pilot study. Community Dent Oral Epidemiol 1999;27:288–97.
36. Villa AE, Anabalon M, Cabezes L. The fractional urinary fluoride excretion in young children under stable fluoride intake conditions. Community Dent Oral Epidemiol 2000;28:344–55.
37. Salama F, Whitford GM, Barenie JJ. Fluoride retention by children from toothbrushing (Abstract no: 1227). J Dent Res 1989;68(Spec issue):335.
38. Whitford GM, Allman W, Shamed R. Topical fluorides: effects on physiologic and biochemical process. J Dent Res 1987;66:1072–8.
39. Haftenberger M, Viergutz G, Neumeister V, Hetzer G. Total fluoride intake and urinary excretion in German children aged 3–6 years. Caries Res 2001;35:451–7.

40. Razak IA. Tooth brushing effectiveness of a group of six year-old uninstructed schoolchildren. Dent J M'sia 1985;8:27–30.
41. Horowitz HS. The need for toothpaste with lower than conventional fluoride concentrations for preschool-aged children. J Public Health Dent 1992;52:216–21.
42. WHO. Monitoring of renal fluoride excretion in community preventive programmes on oral health. Geneva: World Health Organization; 1999.