

Factors affecting dentifrice use and ingestion among a sample of U.S. preschoolers

Steven M. Levy, DDS, MPH Jodi A. McGrady, DMD, MS Patita Bhuridej, DDS, MS
John J. Warren, DDS, MS Judy R. Heilman, BS James S. Wefel, PhD

Dr. Levy is professor and graduate program director, Department of Preventive & Community Dentistry, College of Dentistry, University of Iowa; Dr. McGrady was a graduate student at the time the project was accomplished and is now in private practice, Santa Fe, New Mexico and a Dental Public Health Consultant, ACC Consultants, Albuquerque, New Mexico; Dr. Bhuridej is a graduate student and Dr. Warren is assistant professor, Department of Preventive & Community Dentistry, University of Iowa; Judy R. Heilman is a research assistant, Dows Institute for Dental Research; and Dr. Wefel is a professor, Department of Pediatric Dentistry, University of Iowa and director of the Dows Institute for Dental Research. Correspond with Dr. Levy at steven-levy@uiowa.edu

Abstract

Purpose: This study was performed to assess the actual amount of dentifrice used and ingested and factors associated with use/ingestion among 28 U.S. preschoolers aged 40 to 48 months.

Methods: Using their regular dentifrice brands/flavors and small child-sized toothbrushes (Oral-B® 5), the participants or their parents placed dentifrice on toothbrushes three times to assess the quantity used and its consistency. Their brushing behaviors were observed and the amounts of dentifrice ingested were indirectly measured. Afterward, the parents and children placed a "pea-sized" amount of dentifrice on their toothbrushes.

Results: The participants were generally consistent in quantity applied, averaging 0.256 g (range 0.035 g - 0.620 g; standard deviation 0.177 g) of dentifrice per brushing. Children, either alone or with parental assistance, placed more dentifrice than either mother or father alone ($P=0.007$). The estimated mean ingested fluoride was 0.17 mg F per brushing, an average of 62% of the amount of dentifrice used (range up to 98%). Amount of ingested fluoride was positively associated ($P<0.05$) with the amount of dentifrice used, and negatively associated with parental assistance in brushing. When asked to apply a pea-sized quantity, the mean quantity applied was 0.314 g (range 0.064 g-0.521 g).

Conclusions: This study further supports the use of small amounts of dentifrice in young children, because they ingest substantial proportions of dentifrice. (*Pediatr Dent* 22:389-394, 2000)

In North America, several studies have shown that the prevalence of permanent tooth dental fluorosis has increased in both fluoridated and non-fluoridated communities, compared to that originally reported by Dean.¹⁻⁹ Even though most of the increase is in the milder forms^{3-6,8,10,11} and may not be considered a public health problem, it certainly can be considered an esthetic problem, especially in the anterior teeth.¹²⁻¹⁴

Early use of fluoride dentifrice has been documented in a number of studies as a risk factor for dental fluorosis in both fluoridated areas^{7-8,15-17} and non-fluoridated areas.¹⁸⁻²¹ Almost all dentifrices sold in Canada and the United States are fluoridated.^{22,23} Young children lack complete mastery of the

swallowing reflex,^{20,21,23,24} and children under six years of age may ingest 25-65% of the dentifrice placed on the toothbrush.^{10,25,26} Moreover, most children start brushing by the age of 18 to 24 months,²⁷⁻²⁹ and studies have found greater ingestion of dentifrice at younger ages.^{25,26,30}

In 1992, Naccache et al.²⁶ reported that the amount of dentifrice used was the strongest determinant of the amount ingested. They reported the highest amount of dentifrice use (mean 0.618 g) by the youngest group (2-year-olds) compared to older groups of 3-, 4-, and 5-year-olds (0.529, 0.446, and 0.516 g, respectively).²⁶ Brushing activities, including rinsing and expectoration, were reported to be associated with fluoride ingestion in several studies.^{26,31-34} In 1980, Baxter found that children aged 5 to 16 years who chose to use a beaker of water for rinsing ingested less than those using other methods.³¹ Children who did not rinse their mouths ingested 0.075-0.21 mg F more compared with those who rinsed their mouths.^{26,32} Sjögren et al. reported that the number of times rinsing can affect the degree of fluoride ingestion.³⁴ Other related factors are the flavors and types of dentifrice, which can affect the amount used and the time spent in brushing.^{24,29,31} A study of 16- to 40-month-old children, with a questionnaire response rate of 25-30%, reported the trend of less dentifrice use in families with income greater than \$35,000 a year.³⁵ Parent education was also suggested to be associated with total fluoride ingestion in children.³⁵ In a study of 6- to 14-year-olds, parents' educational level was associated with fluorosis prevalence.⁶ Therefore, parental assistance in brushing and placing dentifrice may also affect amount used and ingested.

Recently, a pea-sized amount of fluoride dentifrice has been more consistently recommended for preschoolers,²² however, few recent studies have been conducted on the amount of dentifrice actually used by preschoolers.^{24,35,36} In addition, no U.S. study has been published that assessed the factors associated with dentifrice use and ingestion among preschoolers, including associations between the actual amounts of dentifrice used and ingested and gender, age, and brushing behaviors. Therefore, the purpose of this study was to investigate U.S. preschool

Table 1. Descriptive Statistics Concerning Dentifrice Application Quantities

	N	Mean (SD)	Median	Minimum	Maximum
1st Application (g)	28	0.244 (0.177)	0.224	0.040	0.805
2nd Application (g)	28	0.281 (0.232)	0.210	0.035	0.950
3rd Application (g)	28	0.244 (0.176)	0.171	0.023	0.642
The Average Amount (g)	28	0.256 (0.177)	0.213	0.035	0.620

children’s dentifrice usage, estimated fluoride ingestion, and factors associated with dentifrice use and ingestion.

Methods

A convenience (non-random) sample of 28 three- to four-year-old children was recruited from the Iowa Fluoride Study, a longitudinal cohort study of fluoride exposures, dental fluorosis, and dental caries.³⁷ The study was approved by the Institutional Review Board (IRB) at the University of Iowa. When originally recruited at the time of the birth of their child, parents provided information about their family income and their educational level.³⁷ After again obtaining informed consent, subjects and their parents participated in three parts of the study conducted at a central location on a single day in May 1998.

Prior to reporting for the study, participants were asked what brand and flavor of dentifrice they most frequently used. These specific products were then purchased and used for all 3 parts of the study.

Part 1: Three Oral B® 5 (small child-sized) toothbrushes were provided to each child/parent. Each toothbrush was pre-weighed using an Ohaus® Electronic Balance. Either the parent or child, whoever normally placed the dentifrice at home, placed the child’s regular brand of dentifrice on toothbrushes three times to assess the quantity used and its consistency. The person placing the dentifrice (child, parent, or both) was recorded. After each placement, the toothbrush was re-weighed and the quantity of dentifrice placed on the brush was determined.

Part 2: To simulate the child’s normal-brushing activities, a single full brushing session was conducted and observed. The child’s teeth were brushed by the person(s) who usually brushed (child, parent, or both) using one of the three toothbrushes on which dentifrice had just been placed. The child/parent were asked to follow normal patterns of brushing, rinsing, and expectorating. Deionized (nonfluoridated) water, cups and a beaker were provided for rinsing and expectorating, as needed. The numbers of expectorations before rinsing, rinses, and expectorations after brushing were recorded. The time spent brushing and parent’s assistance in brushing were also recorded. After brushing, any dentifrice remaining on the child’s face was removed with a tongue blade. The toothbrush and tongue blade, if used, were rinsed into the beaker with deionized water. The contents of the beaker were then analyzed for fluoride.

To estimate the amount of dentifrice ingested, the “expectorant,” including remaining dentifrice, saliva, and rinse (deionized) water, was then weighed, mixed thoroughly with a magnetic stirrer, and a 5-ml sample was removed while still mixing. The 5-ml sample was then mixed using a vortex and single or duplicate samples were immediately removed for fluo-

ride analysis using a modified Taves microdiffusion method.³⁸ After diffusion, the fluoride concentration was determined using a combination fluoride ion specific electrode (Orion® Research Model 96-09-00) in conjunction with an expandable ion Analyzer (Orion® Research Model EA 920). Fluoride standards ranging from 0.1 to 10 ppm fluoride were used. All dentifrices used were assumed to contain 1100 ppm F because consultation with manufacturers (and the American Dental Association) revealed that proprietary information related to the unique chemical formulations of each product, which were not available to us, would be needed to determine the actual fluoride concentration for a given batch of dentifrice.

The quantity of fluoride presumed ingested was then determined by subtracting the estimated expectorated fluoride from the total amount of fluoride in the quantity of dentifrice applied to the brush. The final results were reported in milligrams of fluoride.

Reproducibility of the “expectorant” analyses was calculated as the difference between the duplicate or repeat analyses expressed as a percentage of the mean reading. Twenty-nine percent (8 out of 28 subjects) were duplicated and analyzed on the same day. In addition, 11 percent of the samples (3 out of 28) were repeatedly analyzed on separate days.

Part 3: The parent was asked to place a “pea-sized” amount of dentifrice on a new pre-weighed Oral B® 5 toothbrush. Then, the child, supervised by the parent, placed a “pea-sized” amount of dentifrice on another pre-weighed toothbrush. The toothbrushes were weighed again to determine the amount of dentifrice they perceived to be “pea-sized.”

The results were analyzed using the SPSS software version 7.5³⁹ with $P < 0.05$ considered statistically significant. The Kolmogorov-Smirnov test was used to test the normality of the data. Because the amounts used and ingested were not normally distributed, the Mann-Whitney U test and the Kruskal-Wallis test were used in assessing the relationships between these amounts and other categorical factors. The Spearman correlation coefficient test was used in assessing associations between continuous variables. The Wilcoxon Signed Rank test and the Friedman test were used to test for differences among paired data.

Results

The mean age of the 28 participants was 44 months (SD = 2.53), ranging from 40 to 48 months. Twelve were male and 16 were female. Their mothers’ mean age was 34.8 years (SD = 3.28), ranging from 29 to 40 years old. Data from an interview at the time the children were born showed that 25% of the participants’ mothers had graduate or professional school training, 54% had 4-year college degrees, 11% had 2-year college degrees, and 11% had only high school or some college. The family incomes were: 43% higher than \$60,000, 21%

Table 2. Descriptive Statistics Concerning Brushing Time, Rinsing Habits, and Dentifrice Ingestion

	N	Mean (SD)	Median	Minimum	Maximum
Total Brushing Time(s)	27*	48.07 (28.44)	48.00	9.00	104.00
Number of Times Expectorating after Brushing (before Rinsing)	28	0.71 (0.81)	1.00	0.00	3.00
Number of Times Rinsing	28	1.60 (1.42)	1.00	0.00	6.00
Number of Times Expectorating Rinse	28	0.86 (1.48)	0.00	0.00	6.00
Amount Recovered (mg F)	28	0.08 (0.07)	0.05	0.00	0.28
Amount Not Recovered (Presumed Ingested) (mg F)	28	0.17 (0.15)	0.12	0.00	0.52
Percentage F not Recovered (Presumed Ingested) (%)	28	62.45 (27.51)	69.14	-7.70	97.99

*Brushing time was not recorded for one subject.

\$50,000 to \$59,999, 11% \$40,000 to \$49,999, and 25% less than \$40,000 per year.

In Part 1 of the study, 89% of participants used dentifrice flavored for children. The parents applied the dentifrice in 80% of cases, both parent and child applied dentifrice in 11% of cases, and dentifrice was applied by the child alone in 11% of cases.

The distribution of triplicate dentifrice placements is summarized in Table 1. In addition, 36% placed dentifrice averaging 0.300 g or greater, 7% placed an average of 0.250 to 0.299 g of dentifrice, 11% placed 0.200 to 0.249 g of dentifrice, and 46% used less than 0.200 g of dentifrice on their brushes. The average of absolute differences between placements by the same participant was 0.082 g, ranging from 0.009 g to 0.454 g. The average of maximum absolute differences among placements per person was 0.123 g, ranging from 0.014 to 0.681 g. Overall, there was good consistency in their triplicate placements (Friedman Test, $P = 0.491$).

When children placed dentifrice by themselves ($N = 3$), the amount used (median = 0.545 g) was greater than when dentifrice was placed with parent's help (median = 0.470 g, $N = 3$) or by their parents alone (median = 0.226 g by 3 fathers, 0.173 g by 19 mothers). When children who placed their dentifrice with and without parental assistance were combined ($N = 6$), the amount placed (median = 0.508 g) was significantly greater than that placed by either mother or father (median = 0.174 g, $N = 22$) (Mann-Whitney U test, $P = 0.007$).

Amount of dentifrice used was not significantly different by gender or age of the child, mother's age or educational level, family income, or whether the dentifrice was regular-flavored or flavored for children.

For Part 2 of the study, summary data on brushing time, rinsing and expectorating, and amount and percent of fluoride not recovered (presumed ingested F) are shown in Table 2. The quantities of fluoride presumed ingested ranged up to 0.52 mg F, and averaged 0.17 mg F (median = 0.12 mg F). The percentage of fluoride presumed ingested ranged as high as 98% of the amount used, with a mean of 62% and median of 69%. Seventy-one percent of the children ingested more than half of the dentifrice used, with 50% ingesting more than three-fourths of the dentifrice used. The distribution of estimated percentages of dentifrice ingested are shown in Figure 1.

Fifteen of 28 cases received parental assistance while brushing. Right after brushing, 15 of the children expectorated before rinsing with water; 11 children expectorated once, three did twice, and one child expectorated three times. Ninety-three percent rinsed at least once. Among these 26 children, 65% rinsed once, 23% rinsed twice, 8% rinsed five times, and 9% rinsed six times. After rinsing, 12 of the 26 children expectorated at least once, with 7 (of 12) expectorating once, 3 twice, one five times, and another six times. After rinsing, 54% of the children swallowed rinses at least once.

The amount of fluoride ingested was significantly associated with the amount of dentifrice used ($r = 0.833$, Spearman correlation coefficient), but not with child's age (in months), mother's age, and total brushing time. Also, the amount ingested was not significantly different between regular-flavored dentifrice and dentifrice flavored for children, gender of child, mother's education level, and family income. The amount of fluoride ingested was not significantly related to number of times the child expectorated (before and after rinsing) or to the number of rinsings. In contrast with results for the amount used, the amount of fluoride not recovered and presumed ingested was not associated with the person placing the dentifrice.

Even though the amount of fluoride ingested was not significantly associated overall with the time of brushing ($r = 0.196$, Spearman correlation coefficient), the amount ingested by the group receiving parental assistance in brushing was significantly greater than the group that did not receive parental assistance, with median = 0.19 mg F ($N = 15$) vs. median = 0.06 mg F ($N = 13$) (Mann-Whitney U test, $P = 0.04$).

The median recorded brushing time (50 seconds) for the group that had parental assistance ($n = 15$) was significantly greater (Mann-Whitney U test, $P = 0.017$) than the group without assistance of the parent (27 seconds, $N = 12$). Parents' assistance in brushing was not significantly related to the children's brushing behaviors, including rinsing, and expectorating before and after rinsing. Also, gender of the children was not associated with their brushing behavior.

Same day duplicate reproducibility from the "expectorant" samples ranged from 89.1% to 99.9%, averaging 96.5% ($N=8$). Separate day repeat analysis reproducibility ranged from 90.0% to 99.0%, averaging 93.9% ($N=3$).

Table 3. Descriptive Statistics Concerning Application of "Pea-sized" Quantity of Dentifrice

	N	Mean (SD)	Median	Minimum	Maximum
"Pea-sized" amount placed by parents (g)	28	0.314 (0.118)	0.327	0.064	0.521
"Pea-sized" amount placed by children (g)	28	0.305 (0.239)	0.271	0.007	1.161

Table 3 shows the results from Part 3 of this study. When asked to place a "pea-sized" quantity of dentifrice, the 28 parents placed an average of 0.314 g (SD = 0.118). The 28 children, largely supervised by parents, placed a mean of 0.305 g (SD = 0.239). For those 25 parents who placed or assisted with placement of dentifrice for their child in Part 1, the amount of dentifrice used (median = 0.175 g, mean = 0.227 g) in Part 1 (their normal quantity used) was not significantly different (Wilcoxon Signed Ranks test, $P = 0.104$) from the amounts they placed as the recommended "pea-sized" amount (median = 0.304 g, mean = 0.300 g).

Discussion

Study findings should be generalized with caution because of the small, recruited (convenience) sample. In addition, although the study attempted to duplicate "normal" brushing habits of the children by such measures as having each child use his/her typical brand and flavor of dentifrice, the research environment where the study was conducted may have altered the behavior of parents and children. For example, all subjects brushed with an Oral B® 5 toothbrush, a child's toothbrush with a small head size (5 mm X 15 mm). Children who usually used a different toothbrush may have used quantities of dentifrice that were different from their usual quantities. In particular for those children who normally used toothbrushes larger than the Oral B® 5, the quantity of dentifrice they typically use may have been underestimated.

Also, the estimated quantities of ingested fluoride were calculated assuming all dentifrices contained 1100 ppm fluoride,

since it was not feasible to calculate actual dentifrice fluoride concentrations due to complexities about the formulations, etc. For products with actual fluoride concentrations higher (or lower) than the 1100 ppm, estimated fluoride ingestion in mg (and in percentage) would be underestimated (or overestimated) accordingly. Consistent with a study we conducted in a group of 1- to 4-year-olds in Iowa,³⁶ most of the parents (89%) placed dentifrice for their children. In 1988, Bruun and Thylstrup reported that 97% of Danish parents dispensed dentifrice to their 3-year-olds in their study.³⁹ In this study, we found that 46% of the participants brushed by themselves, compared to 38% in our earlier study, in which the children were younger.³⁶ Bruun and Thylstrup found that 79% of the children rinsed while brushing, and our study indicated that 93% of the participants did so.³⁹ In this study, more than half of the children expectorated at least once after brushing (before rinsing) and 46% expectorated the rinse after brushing. This compares with 32% of 2- to 4-year-olds who expectorated rinses in our earlier study and 29% to 33% of 16- to 40-month-old Indiana children expectorated after brushing.^{35,36}

The average amount of dentifrice used in this study (0.256 g) was lower than in the other studies in North America^{24-26,28,29,32,35-36,41,42} and Europe,^{27,31,40,43,44} as summarized in Table 4. The current study group may have used a smaller amount of dentifrice because their parents were in the Iowa Fluoride Study and had greater awareness of children's oral health recommendations to use small quantities of dentifrice or "pea-sized" amounts. Or, the difference may have been due to the higher educational level and family income of the parents in this study vs. others. The smaller amount used in this study also may result from the small size of toothbrush that was used (Oral B® 5). Most subjects showed overall consistency in the amount used in the replicate placements.

The person who placed the dentifrice was a significant factor in this study. Children alone placed significantly more dentifrice than did parents or children with parental assistance. Mother's education and gender of the child were not significantly related to the amount of dentifrice used or the amount of fluoride ingested. This finding is supportive of the results of Mascarenhas and Burt that gender and mother's education were not related to severity of fluorosis in a multivariable model.²¹

The estimated mean of 0.17 mg of fluoride ingested by the children in this study was consistent with the range (0.12 to 0.38 mg F for 1000 ppm dentifrice) as reviewed by Beltrán and Szpunar, yet less than the findings (0.42 – 0.58 mg F, with 1000 to 1100 ppm F hypothetical concentrations) of Rojas-Sanchez et

Table 4. Summary of Previous Studies of Dentrice Use Among Young Children Ages 3-5

Authors (year)	Study Site	Ages (years)	Mean Dentifrice Use (g)
Ericsson & Forsman (1969) ⁴³	Sweden	4	0.45
Hargreaves et al. (1972) ⁴¹	Canada	3-6	1.38
Barnhart et al. (1974) ²⁵	United States	2-4	0.86
Dowell (1981) ²⁷	England	3	0.54
Bruun & Thylstrup (1988) ⁴⁰	Denmark	3	1.10
Simard et al. (1989) ³²	Canada	2-3	0.46
Simard et al. (1989) ³²	Canada	4	0.78
Naccache et al. (1990) ⁴²	Canada	3	0.50
Naccache et al. (1990) ⁴²	Canada	5	0.47
Naccache et al. (1992) ²⁶	Canada	2	0.45
Naccache et al. (1992) ²⁶	Canada	5	0.62
Adair et al. (1997) ²⁴	United States	2-5	0.51 adult flavor 0.69 child flavor

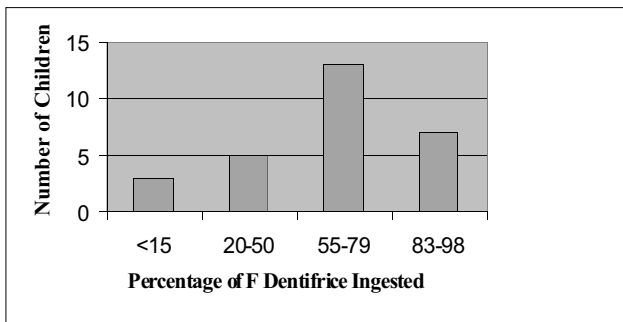


Fig 1. Estimated percentage of dentifrice used that was ingested.

al.^{30,35} The amount of dentifrice used in this current study was considered low and all dentifrices were assumed to contain 1100 ppm F, since determination of the actual concentration of fluoride in each dentifrice product requires complex, individualized methodologies, and proprietary information about the particular product. Again, if the concentration of fluoride was actually greater, the amount presumed ingested would also be greater.

The mean percentage of fluoride ingested in this study was 62%. This figure is consistent with ranges reported in the literature as 59% to 65% in 2- to 3-year-olds,²³ 25% to 65% in young children,²⁴ and 28% to 97% in 16- to 40-month-old children.³⁵ However, the method used in our study might provide a slight overestimate of the amount of dentifrice ingested compared with other methods because all unrecovered components were presumed ingested, rather than measuring ingestion directly.⁴⁰ Overall, the findings support the concept that expectoration of the dentifrice has not yet been fully mastered by young children, either because of lack of training, inadequate swallowing reflex, or both.³⁶

An important factor related to the amount of fluoride ingested in this study was the amount of dentrice used. This finding was consistent with the studies by Naccache et al.²⁶ and Glass et al.⁴⁴ Parental assistance in brushing was another factor found associated with the duration of brushing. The fact that children who had parental assistance while brushing ingested more fluoride than children who brushed by themselves may have been due to longer brushing with parents' desires to achieve excellent oral hygiene and caries prevention for their child coupled with a lack of knowledge regarding fluorosis and fluoride ingestion.

In contrast with other studies,^{24,29,31} the amount of fluoride ingested from dentifrice flavored for children was not significantly higher than that from regular-flavored dentifrice. Other factors that were not associated with fluoride ingestion were brushing behaviors, including mode of rinsing and expectorating, in contrast with other studies.^{24,26,33,34} Unlike the study of Rojas-Sanchez et al.,³⁵ we found that parents' educational level and family income were not significantly related to the amount of fluoride ingested. However, this may be due to the small convenience sample used.

Currently, we do not know exactly what "pea-sized" amount means. From this study, the parents' perceptions of "pea-sized" averaged 0.314 g overall. The parents who placed the dentifrice for their children perceived that "pea-sized" was about 0.300 g (mean), which was not significantly different from the actual amount they placed for their children's brushing (mean

= 0.227 g). Therefore, the recommendation of using the "pea-sized" amount may already be working for this group of parents participating in the Iowa Fluoride Study, and directing them to use a pea-sized amount would not result in reduced quantities used. However, Rojas-Sanchez et al. reported that fewer than 50% of children used a "pea-sized" amount of dentifrice in their study when parents were asked to estimate dentifrice used.³⁵ Thus, in such populations, professionals' instructions to use pea-sized amounts could make more of a difference.

This study further supports that young children ingest substantial proportions of dentifrice. Professionals should use this knowledge to help motivate parents to properly supervise and assist their children's brushing, with the goal of reducing the potential risk of fluorosis. Parents should be provided sufficient knowledge about using small amounts of dentifrice and trying to avoid having their children ingest dentifrice. Additional studies with larger, more varied samples should be conducted to better understand the factors that affect dentifrice ingestion in young children and monitor changes in behavior as a result of increased emphasis on use of small quantities of dentifrice.

Conclusions

1. The participants ingested a mean of 62% of the dentifrice they used per brushing.
2. The ingested amount was significantly associated with the amount of dentifrice used.
3. Surprisingly, the amount ingested by the group with parental assistance was significantly higher than those without parental assistance.
4. Parents should be encouraged strongly to have their young children use small quantities of fluoride dentifrice in order to reduce risks of dental fluorosis.

The authors would like to thank all participants and staff of the Iowa Fluoride Study for their great help during this study. (Supported by NIH grants RO1-DE09551 and P30-DE10126)

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