REVIEW

A review of fluoride intake from fluoride dentifrice

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There has been substantial professional discussion in recent years about the appropriate use of fluorides, with emphasis on achieving substantial dental caries prevention while minimizing risks of dental fluorosis. Important aspects of the subject were addressed at several recent international meetings:

☐ A joint IADR/ORCA International Symposium on Fluorides held in Georgia in 1989.
☐ An American Association of Public Health Dentistry Symposium on Appropriate Use of Fluorides held in Boston in 1990.

The U.S. Department of Health and Human Services' 1991 Review of Fluoride: Benefits and Risks also reviewed this subject and emphasized the need for increased attention regarding the "prudent health practice of using no more (fluoride) than the amount necessary to achieve a desired effect" and the need to "avoid excessive and inappropriate fluoride exposure." It also recommended that: "Parents should educate young children to minimize swallowing of fluoridated toothpaste and to use only small amounts of toothpaste on the brush."

The purpose of this paper is to review in detail the existing literature concerning fluoride intake from fluoride dentifrice among young children, in order to provide the practitioner with a better understanding of the importance of avoiding excessive ingestion of toothpaste by young children.

With use of fluoride dentifrice almost universal in the United States and Canada, fluoride ingestion from dentifrice is an important consideration. Several studies have explored usage and ingestion of fluoride from dentifrice among diverse age-groups, but with various methodologies, often under artificial conditions. Despite these limitations, the studies established that ingestion of fluoride from toothpaste is common and often substantial. Most mothers start brushing their children's teeth with toothpaste at a young age. Because fluoride dentifices available in the United States and Canada generally have 1000-1100 ppm fluoride, about 1.0 mg of fluoride is being used (or ingested) with each g of dentifrice used (or ingested). Extra-Strength Aim® contains 1500 ppm fluoride and is available in the United States. A full strip of dentifrice covering an adult-sized toothbrush is often more than 1.0 g of dentifrice, while a strip covering a child-sized brush is approximately 0.75 to 1.0 g.

Relatively few studies have reported toothbrushing habits and toothpaste use among preschool children. The studies with younger preschool children are presented here in the most detail, because they are most important in our consideration of risks of fluorosis. Although there is increasing evidence for the importance of the post-secretory or maturational state of enamel formation, the most critical period of fluorosis risk for

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the esthetically important maxillary central incisors is believed to be about 20 to 28 months.\textsuperscript{8-14}

**REVIEW OF THE LITERATURE**

Palmer and Prothero reported that 72 percent of British seventeen-month-olds and 98 percent of three-year-olds used fluoridated toothpaste with the majority starting by twelve months of age.\textsuperscript{15} Among those using toothpaste, 29 percent of seventeen-month-old children and 55 percent of the three-year-old children reportedly brushed at least twice daily. Twenty-three percent of the parents of three-year-olds reported that their children swallowed most of the toothpaste and 24 percent reported that their children ate toothpaste at other times.

Dowell interviewed 115 British mothers concerning initiation of use of toothpaste with their three-year-olds.\textsuperscript{16} All children had begun toothbrushing and 96.5 percent were reportedly brushing at least once per day, with about half of the children brushing twice per day or more. Forty-one percent reported starting to use toothpaste by twelve months of age and 74 percent had begun by eighteen months. Eighty-eight percent of mothers reported that children liked the taste of the toothpaste and 8 percent made unsolicited comments about the children sometimes eating toothpaste directly from the tube.

Several other recent studies also showed substantial toothbrushing and use of fluoride dentifrice among those younger than age three. In a Norwegian study, 83 percent of mothers of children eighteen to thirty-six months old reported regularly brushing the children's teeth.\textsuperscript{17} In a retrospective study in the Netherlands, 70 percent of eighty-three children were reported to have used fluoride toothpaste at least twice daily.\textsuperscript{18} Szpunar and Burt found that more than 50 percent of six- to twelve-year-old Michigan children reportedly had their teeth brushed before age two.\textsuperscript{19} In their case-control study of fluorosis in Toronto, Osuji \textit{et al} reported that 53 percent of 139 eight- to ten-year-old children (27 percent of controls vs 82 percent of cases) had begun brushing with fluoride toothpaste before the age of twenty-five months.\textsuperscript{20}

The Table summarizes results from many of the studies of use and ingestion of the dentifrice. To facilitate comparison, all results are presented in grams (g) of dentifrice used or ingested. To convert to milligrams (mg) of fluoride for an individual patient, one must know which dentifrice is being used. For 1000 -1100 ppm fluoride dentifrices, the number of mg fluoride approximately equals the number of grams of dentifrice. For 1500 ppm dentifrices, the number of mg fluoride equals 1.5 times the grams of dentifrice. (In several places in the table, the mean proportion (percentage) of dentifrice ingested does not equal the mean quantity ingested divided by the mean quantity used. The reasons for this are due to round-off to two decimal places and because the mean proportions ingested are calculated directly from the individuals' proportions ingested and not from the group totals.)

Ericsson and Forsman supervised toothbrushing by ten Swedish six-year-olds and performed the brushing for ten four-year-olds. All rinsings and toothpaste on the lips were collected and the fluoride level determined by a fluoride ion electrode. In five cases, the fluoride left on the toothbrush after rinsing was analyzed and found to be less than 2 \(\mu g\) (0.002 mg), so this source was neglected in future calculations. Two different toothpastes were used several days apart, with generally similar results. The younger children used an average of about 0.45 g of paste and retained an average of 0.13 g (range of 0.04 to 0.30 g) for an average of 30 percent ingested. Among six-year-olds, mean use was 0.45 g with mean retention of 0.12 g (range of 0.06 to 0.19 g) for an average of 26 percent ingested.

Hargreaves \textit{et al} conducted excretion studies on toothpaste ingestion among 105 British children age three to six from a low fluoride area.\textsuperscript{22} Fluoride ingestion was determined by using urinary excretion as a marker, with urine samples drawn after using placebo pastes and monofluorophosphate (MFP) paste for comparison purposes. Assuming constant fluoride ingestion from sources other than dentifrice, ingestion from dentifrice was calculated as the difference when using the MFP paste vs placebo. Also, a subset of twenty-seven children later received 2 mg of fluoride per day on sugar lumps and excretion was determined to average about 20 percent. This 20 percent factor and the fluoride concentration in the toothpaste were used to calculate ingested quantity from excreted quantity among the 105 children. Sixty-eight percent of children were estimated to ingest up to 0.25 g paste/day, 22 percent more up to 0.50 g, and 10 percent greater than 0.50 g. (Note that this study is not summarized in the table because means and ranges were not included in the article.)

Hargreaves \textit{et al} reported on the use and ingestion of toothpaste among forty-four British children age three to six years.\textsuperscript{23} In contrast with their previous excretion marker study where "failure to recover any part of the ingested marker will tend to underestimate the amount
Table 2. Dentifrice use and ingestion.

<table>
<thead>
<tr>
<th>Study</th>
<th>Age group</th>
<th>Number</th>
<th>Dentifrice used per brushing (g)</th>
<th>Dentifrice ingested per brushing (g)</th>
<th>Mean percentage ingested</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mean</td>
<td>Range</td>
<td>90%</td>
</tr>
<tr>
<td>Ericsson and Forsman</td>
<td>4</td>
<td>10</td>
<td>0.45</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1969)</td>
<td>6</td>
<td>10</td>
<td>0.45</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hargreaves et al.</td>
<td>3-5</td>
<td>44</td>
<td>1.38</td>
<td>0.18-5.14</td>
<td>2.04</td>
</tr>
<tr>
<td>Barnhart et al.</td>
<td>2-4</td>
<td>62</td>
<td>0.86</td>
<td>0.19-2.41</td>
<td></td>
</tr>
<tr>
<td>(1974)</td>
<td>5-7</td>
<td>56</td>
<td>0.94</td>
<td>0.15-2.08</td>
<td></td>
</tr>
<tr>
<td></td>
<td>11-13</td>
<td>73</td>
<td>1.10</td>
<td>0.31-2.00</td>
<td></td>
</tr>
<tr>
<td></td>
<td>20-35</td>
<td>60</td>
<td>1.30</td>
<td>0.42-3.29</td>
<td></td>
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<tr>
<td>Glass et al.</td>
<td>8-10</td>
<td>67</td>
<td>1.04</td>
<td>0.23-5.27</td>
<td>1.57</td>
</tr>
<tr>
<td>(1975)</td>
<td>5-16</td>
<td>85</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>5-6 only</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dowell (1981)</td>
<td>3</td>
<td>115</td>
<td>0.55</td>
<td>0.07-1.97</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>63</td>
<td>1.1</td>
<td>0.17-3.9</td>
<td>1.62</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>31</td>
<td>1.5</td>
<td>0.20-3.7</td>
<td>2.32</td>
</tr>
<tr>
<td>Bruun and Thystrup</td>
<td>9</td>
<td>27</td>
<td>2.3</td>
<td>1.20-4.3</td>
<td>3.13</td>
</tr>
<tr>
<td>(1980)</td>
<td>5</td>
<td>24</td>
<td>1.6b</td>
<td>0.34-2.5a</td>
<td>1.8b</td>
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<td></td>
<td>16</td>
<td>9</td>
<td>3.4</td>
<td>2.10-4.9</td>
<td>4.3a</td>
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<tr>
<td></td>
<td>16b</td>
<td>25</td>
<td>2.1b</td>
<td>0.72-4.9b</td>
<td>2.9b</td>
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<tr>
<td>Salama et al.</td>
<td>3-10</td>
<td>19</td>
<td>1.0b</td>
<td>1.0-1.0b</td>
<td>1.0b</td>
</tr>
<tr>
<td>(1989)</td>
<td>2-3</td>
<td>5</td>
<td>0.46</td>
<td></td>
<td></td>
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<tr>
<td>Simard et al.</td>
<td>4</td>
<td>9</td>
<td>0.78</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1989)</td>
<td>5</td>
<td>9</td>
<td>0.65</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Naccache et al.</td>
<td>3</td>
<td>23</td>
<td>0.50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1990)</td>
<td>5</td>
<td>25</td>
<td>0.47</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Simard et al.</td>
<td>1</td>
<td>15</td>
<td>0.16</td>
<td>0.03-0.5</td>
<td>0.40</td>
</tr>
<tr>
<td>(1991)</td>
<td>2</td>
<td>36</td>
<td>0.62</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Naccache et al.</td>
<td>4</td>
<td>81</td>
<td>0.45</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(in press)</td>
<td>7</td>
<td>77</td>
<td>0.50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maurice et al.</td>
<td>1-4</td>
<td>59</td>
<td>0.47a</td>
<td>0.01-2.38a</td>
<td>0.86a</td>
</tr>
</tbody>
</table>

1. Average of results obtained with two different dentifrices
2. Results from two-week usage and diary period
3. For this study, these are 75th percentiles, not 90th
4. Dentifrice tube orifice was 21% smaller than for other subgroups
5. All subjects used 1.0 g
6. Single observation
7. Weekly use and diary period

Note: The quantity of fluoride in mg can be calculated from the quantity of dentifrice in g as follows: if 1000 ppm fluoride, then number of mg fluoride = number of g of dentifrice; if 1100 ppm fluoride, then number of mg fluoride = 1.1 times the number of g of dentifrice; and if 1500 ppm fluoride, then number of mg fluoride = 1.5 times the number of g of dentifrice.

The mean proportion of toothpaste ingested was 28 percent. Overall, the patterns were similar to those from their previous study, although the quantities estimated to be ingested were somewhat higher. The authors noted that analysis-of-variance showed that the variation among children was substantially greater than that within children.

Barnhart et al used a one-way mirror to observe Ohio individuals' directed to follow their normal toothbrushing habits. A number of subjects who dropped dentifrice were excluded from the results. As seen in the Table, subjects were from four age-groups. Ninety-five percent of the two- to four-year-olds had their mothers accompany them and apply the dentifrice to the toothbrush and mothers brushed the teeth in 40 percent of the cases. Double deionized water was used, all rinsings were collected and non-ingested quantities were...
determined by atomic absorption spectroscopic analyses for LiCl which was included in the dentifrice as a chemical tracer. The youngest children brushed once each, while the other age-groups conducted duplicate brushings. Most subjects used substantial quantities of dentifrice, although older subjects used somewhat more. The age-related differences in ingestion were dramatic with mean ingestion of 0.30 g per brushing among two- to four-year-olds (35 percent of that used) and 0.13 g (14 percent) among those age five to seven. Ten percent of those age two to four ingested 0.73 g of paste or more per brushing. Barnhart et al reported that within-patient variation in ingestion from duplicate brushings for those age five to seven or older was greater than between-patient variation.24

Glass et al reported on sixty-seven children age eight to ten years who conducted three replicate trials with the quantity not recovered from the toothbrush or rinsings being considered as ingested.25 Brushing and rinsing were to be carried out as normally done by the children. A fluoride specific electrode was used for determination of the fluoride content. The range of toothpaste used was from 0.23 to 2.57 g with a mean of 1.04 g. The mean weight ingested was 0.12 g with a range of 0 to 0.41 g. The proportion of dentifrice ingested ranged from 0 to 32 percent, with a mean of 12 percent. All of these children were old enough to be beyond the age of risk of fluorosis to the majority of the permanent teeth.

Baxter studied supervised toothbrushings on three occasions by eighty-five British schoolchildren age five to sixteen.26 By use of atomic absorption spectroscopy, the total calcium content of the toothpaste expelled from the mouth or remaining on the toothbrush was determined and the weight of toothpaste ingested was estimated. The overall mean quantity ingested was 0.19 g, with 70 percent averaging less than 0.25 g ingested and about 95 percent averaging less than 0.5 g ingested per brushing. Ingestion values were substantially higher, however, for the eight children age five to six with a mean of 0.27 g ingested. Five of the eight young children had at least one reading greater than 0.3 g ingested and rinsing with water did not lead to lower ingestion among five- to six-year-olds.

Dowell asked 115 mothers of three-year-olds to place their child's usual amount of toothpaste on a pre-weighed child's toothbrush.16 Reweighing of the brush allowed the amount of toothpaste used to be calculated. Toothpaste use ranged from 0.07 g to 1.97 g with a mean of 0.54 g. All mothers reported that their children swallowed some toothpaste and 64 percent thought that about half or more was ingested. The author commented on the substantial variation among individuals, ranging from "a smear of paste to virtually the maximum quantity which can be loaded on to a child's small toothbrush." Although acknowledging the artificial conditions of dispensing the toothpaste, Dowell concluded that "some children are exposed to fluoride in toothpaste young enough and in large enough quantities for there to be a systemic effect during the formation of not only the permanent dentition but also some of the posterior deciduous teeth." Concern was also expressed over some small children having access to the toothpaste and eating it freely.

Bruun and Thylstrup assessed toothpaste usage during a two-week period among 179 Danish children age three, seven, nine, or sixteen.27 There were sixty-three children age three who were all given the same widely used commercial dentifrice. The total amount of dentifrice used was determined as the difference between the mean weight of the full tubes and that of each child's returned tube. Parents (for the younger children) and older children were instructed to use the toothpaste "in exactly the normal way, and that nobody else should use the tube." Those age three and seven averaged 2.0 brushings per day while nine-and-sixteen-

Non-rinners ingested 75 percent more toothpaste than riners.
year-olds averaged 2.1 to 2.2. For 97 percent of the three-year-olds, the toothpaste was reportedly dispensed by an adult and 79 percent reported a water rinse in connection with the brushing. Fifty-four percent of seven-year-olds reportedly dispensed their own toothpaste and 77 percent reportedly rinsed. The quantity of dentifrice used daily varied substantially. For three-year-olds, the range of daily dentifrice use was 0.17-3.0 g, the mean was 1.1 g, the median was 1.0 g, and 25 percent of children used 1.6 g or more. With the same brand of dentifrice, daily amounts used "increased at a fairly constant rate" with increasing age, to means for seven-year-olds of 1.5 g, for nine-year-olds of 2.3 g, and for sixteen-year-olds of 3.4 g. The authors did not assess quantity of toothpaste actually ingested. However, assuming that three-year-olds swallowed 30 percent and seven-year-olds 15 percent of the toothpaste they used, it was determined that, depending on water fluoride level (<0.2 ppm vs 0.2-0.7 ppm), 35 percent of seven-year-olds would be exceeding from dentifrice alone the recommendation for systemic fluoride supplementation in Denmark.

Salama et al determined the amount of fluoride not recovered from the mouth and presumed ingested after toothbrushing by nineteen children age three to ten. Each child brushed with 1.0 g of 0.1 percent fluoride dentifrice and rinsed, if it was their habit to do so. The fluoride in the expectorate and remaining on the toothbrush was analyzed with a fluoride electrode. Brushing time averaged fifty-nine seconds and was not correlated with age. Seven of nineteen children (37 percent) did not expectorate. The quantity of fluoride not recovered ranged from 0.08 to 0.82 mg with a mean of 0.36 mg and, therefore, the mean proportion ingested was 36 percent. Older children retained less fluoride. The authors concluded that the average amount of ingested fluoride from a single brushing exceeded the average dietary fluoride intake of young children in non-fluoridated areas and was about 75 percent of that in fluoridated areas and that toothpaste is an important source of ingested fluoride.

Simard et al reported pilot study findings concerning twenty-three Quebec children age two to five. They first gathered information from the parents by questionnaire and then, depending on the responses, either the child or a dental hygienist (in lieu of the mother) put the toothpaste on the toothbrush and brushed the child's teeth. Children either rinsed or not as was their habit. Brushing lasted five minutes on average. All fluoride not ingested, and thus rejected, was collected and analyzed by direct determination of fluoride with a fluoride ion-specific electrode. The quantity ingested was the difference between quantity used and rejected. The authors acknowledged that this method tends to overestimate the quantity ingested since all loss is considered ingested, but close attention to recovery of dentifrice was believed to have held this overestimation to a minimum. On the questionnaire, parents reported putting toothpaste on for 77 percent of the children. In 41 percent of the cases, the quantity of toothpaste put on the toothbrush reportedly covered a third or less of the brush, in 50 percent of cases it was from one-third to two-thirds, and in 9 percent it was two-thirds or more. Seventy-eight percent reported that children rinsed their mouths after brushing. From the brushing observations and calculations, it was determined that the overall mean quantity of dentifrice used was 0.66 g, with a mean of 48 percent of it ingested for a mean quantity ingested of 0.30 g. Children not rinsing their mouths ingested approximately 75 percent more paste than did those rinsing (0.45 g vs. 0.25 g). Those age two to three ingested an average of 59 percent of the toothpaste compared with 48 percent for four-year-olds and 34 percent for five-year-olds. By considering frequency of toothbrushing, mean daily quantity of toothpaste ingested was calculated to be

Unrelated to age, the mean quantity used per brushing was 0.50 g.
about 0.67 g. Almost a third of the children were ingesting (from toothpaste alone) more than their age-specific recommended daily total quantity of fluoride.20

The excess ranged from 0.17 mg to 0.76 mg.

Naccache et al assessed the amount of dentifrice used and ingested by forty-eight children age three or five years old.31 All selected children were ones who brushed their teeth themselves, used dentifrice, and placed the toothpaste on the brush themselves. The major purpose of the study was to investigate the variability in the amount of dentifrice used and ingested. Each child had three brushing sessions a week apart with the quantity of fluoride rejected being determined by fluoride ion-specific electrode, and quantity ingested then calculated by subtraction as in their earlier study.29

The mean quantity of dentifrice used by the twenty-three three-year-olds was 0.50 g with 0.18 g ingested compared with means of 0.47 g used and 0.11 g ingested for twenty-five five-year-olds. The average of the proportions ingested were 41 percent for three-year-olds and 30 percent for five-year-olds. Repeated measures analysis of variance was employed to investigate differences in the amounts of toothpaste used, amounts ingested, and proportions ingested. There were no statistically significant differences in the amounts of dentifrice used or ingested across the three brushings, but differences among children were statistically significant. For proportion of dentifrice ingested, differences among children were significant, as was the tendency to ingest a higher proportion the first brushing vs. the second or third, but "the variability was not of an important magnitude." The amounts used and ingested were comparable with those found by Ericson and Forsman with four- to six-year-olds, but lower than those found by Barnhart et al and Hargreaves et al whose ingestion figures may have been inflated due to loss of dentifrice other than from swallowing.21,22,24

In summary, Naccache et al reported that children used and ingested different amounts each brushing, but the differences were minor and largely random.31 Thus, the variation within a given child was probably due to chance and not to the order of brushings. Variability among children was clearly greater than that within children. They recommended that future studies examine larger numbers of children, therefore, instead of smaller numbers repetitively.

Simard et al surveyed fifty-nine parents of Quebec children age twelve to twenty-four months concerning the children's toothbrushing habits and use of fluoride toothpaste.32 Forty-two percent reported using toothpaste and, among those, 48 percent reported beginning before twelve months. Sixty percent reported brushing once per day vs 40 percent more than once per day. Seventeen percent of those less than eighteen months of age used fluoride toothpaste compared with 67 percent of those eighteen months of age or greater. For fifteen of the twenty-five children using a dentifrice, a dental hygienist met with the parent to observe and quantify the amount of toothpaste used by weighing the toothpaste tube before and after. Fifty-three percent used less than 0.1 g, 33 percent used 0.1 g-0.3 g, and 14 percent used more than 0.3 g per brushing. The authors suggested that "with the widespread use of fluoride dentifrice at an early age and the risk of developing dental fluorosis, parents should be advised to delay the use of fluoride dentifrice until the child is older than twenty-four months." This is in contrast with current recommendations to begin using fluoride dentifrice when the first primary tooth erupts.33

Dentifrice use was investigated retrospectively in exposures from birth to age six among sixty-nine school-aged children in Iowa.34 Sixty-two percent reported that their children's teeth were first brushed before age two, 24 percent reported beginning at age two, and 14 percent reported beginning at age three or older. Fifty-four percent reported beginning use of fluoride dentifrice by age two, 39 percent at age two to three, and 7 percent age four or later. Six percent reported that their children began brushing their own teeth before age two and an additional 57 percent brushed their own teeth by age two or three. Parents reported that 36 percent of their children typically brushed twice daily from age two to six, 54 percent reported once daily, and 10 percent reported less than daily brushing from age two to six. Parents used a photograph with pictures of 8 toothbrushes with various quantities of dentifrice to report their children's typical use of dentifrice separately up to age two, age two to three, and age four to five. Prior to age two, 8 percent reportedly used no paste, 27 percent used less than one-quarter of a toothbrush strip (less than about 0.25 g), 26 percent used about 0.25 g, 30 percent used about 0.5 to 0.75 g, and 9 percent used about 1.0 g. At age two and three, 2 percent typically used none, 20 percent used less than 0.25 g, 19 percent used about 0.25 g, 44 percent used about 0.50 to 0.75 g, and 15 percent used about 1.0 g. When age four or five, 59 percent reportedly used about 0.5 to 0.75 g, 29 percent used about 1.0 g, and 12 percent used about 0.25 g or less. These data supported the conclusions of Beltran and Szpunar that young children could ingest enough fluoride from toothpaste alone to be at risk of dental fluorosis.35
Naccache et al recently explored the effects of age, amount of dentifrice used, and rinsing after brushing on the ingestion of fluoride dentifrice among 405 Quebec children age two to seven, with eligibility limited to those brushing their own teeth with toothpaste.\textsuperscript{36} In the 23 percent of the children who did not usually place the toothpaste on the brush themselves, a trained dental hygienist watched the mother at home place the toothpaste, measured the quantity by weighing before and after, and reproduced the quantity for the child at school where a single brushing by each child with a standard toothbrush and toothpaste was observed. As in their previous studies, fluoride contents of the rejected quantities of toothpaste were determined with a fluoride ion-specific electrode and the quantity ingested was derived as the difference between the quantity used and rejected.

The overall mean quantity used per brushing was 0.50 g with the amount used not significantly related to age.\textsuperscript{36} The variability among the two-year-olds was much greater than in the other ages. There was a significant age-related pattern of rinsing, with few of those under age six rinsing their mouths. Quantity ingested declined significantly with increasing age, from a mean of 0.36 mg F (0.33 g of 1100 ppm fluoride toothpaste) for two-year-olds to 0.24 mg F (0.22 g of toothpaste) for four-year-olds and 0.18 mg F (0.16 g of paste) for seven-year-olds. The proportion of toothpaste ingested was significantly related to age, with the mean proportion ingested declining from 65 percent among two-year-olds to 49 percent among three- and four-year-olds to 34 percent among six- and seven-year-olds. The overall mean quantity of fluoride ingested was 0.23 mg F from 0.21 g of 1100 ppm fluoride paste ingested. Among four- and five-year-olds, rinsing was associated with significantly less ingestion of dentifrice (0.17 vs. 0.26 mg F). Younger children swallowed similar quantities of dentifrice regardless of rinsing behavior, probably due to inadequate control of swallowing reflexes.

The older children apparently "had learned to expectorate properly by that age, regardless of their rinsing habits," and ingested less dentifrice whether rinsing or not.

In a longitudinal study of approximately eighty Iowa children from birth to eighteen months in which parents completed questionnaires every three months, parents did the majority of the toothbrushing of the children's teeth at each age.\textsuperscript{37} Sixty-six percent reportedly had teeth brushed regularly at twelve months, 81 percent at fifteen months, and 92 percent at eighteen months. Pictures of toothbrushes with various toothpaste quantities were viewed by the parents. About 25 percent used at least a quarter of a toothbrush strip (about 0.25 g or more) of toothpaste per brushing at twelve, fifteen, and eighteen months. Approximately a third of those used about 0.25 g and two thirds used about 0.5 g or more.

Nowak recently studied toothpaste use among 384 Iowa preschool children up to age five.\textsuperscript{38} Parents were asked to select from pictures of four toothbrushes with various quantities of dentifrice (0.10, 0.25, 0.50, 1.0 g) the one closest to matching their child's typical use. There was a clear trend toward increasing quantity of dentifrice used with increasing age. Overall, 5 percent used about 1.0 g, 36 percent used 0.50 g, 33 percent used 0.25 g, and 25 percent used 0.10 g. Twenty-eight percent of two- to three-year-olds used about 0.5 g or more of dentifrice compared with 44 percent of four- to five-year-olds.

In a recent study of toothpaste use and habits among fifty-nine Iowa children age one to four, parents and children simulated their normal toothbrushing routine during a single observation at the college of dentistry.\textsuperscript{39} They were provided with a preweighed toothpaste tube of the brand and flavor they typically used. Quantity used ranged from 0.01 to 2.39 g with a mean of 0.43

In policy-making discussions, the mean and the distribution of results should be considered.
g. Older children tended to use more toothpaste. No precise measurement of quantity ingested was made, but 54 percent of children ingested most of the toothpaste based on their lack of any rinsing or expectorating. Furthermore, the majority of those who rinsed with water, ingested all or most of the rinse instead of expectorating. Younger children tended to rinse and expectorate less frequently and, therefore, appeared to ingest larger proportions of dentifrice used. Only 5 percent of those less than age two-and-one-half spit out toothpaste vs 32 percent among those age two-and-one-half to four. Children's toothbrushing patterns and toothpaste use at home were then assessed for a one-week period with a diary. By comparison of toothpaste tube weight before and after the week, total weekly use was determined. Mean toothpaste use per brushing was 0.47 g with a range of 0.03 to 1.27 g and mean use per day was 0.77 g (range of 0.03 to 3.21 g). Again, the older children tended to use more toothpaste than did the younger children. Patterns of toothpaste use during observation and from the diary correlated well. In a substudy with twenty-nine of the children, use of dentifrice specially flavored for children was associated with the use of larger quantities of dentifrice than when using regular flavor dentifrice, both across groups of children and for individual children using both products with a crossover design. The preschoolers used a daily average of 0.81 g of dentifrice flavored for children vs 0.66 g of regular flavor dentifrice.

**DISCUSSION**

These studies of dentifrice ingestion were conducted by different investigators using different methods in different nations and settings. Nevertheless, all investigators reported widespread use of fluoride dentifrice, with most children using dentifrice by age eighteen to twenty-four months. There was substantial variation among subjects in their use and estimated ingestion of fluoride dentifrice. The variation within subjects on repeated brushings sometimes was substantial as well. Overall, however, variation among subjects was generally much greater than that within subjects, and variation within subjects was believed to be due to chance with the differences being relatively minor.

Within the age range of two to seven, younger children generally used quantities of toothpaste fairly similar to those used by older children, but ingested larger proportions and quantities. The mean quantities ingested by two- to three-year-olds were approximately 0.3 g per brushing and the ingested portion of toothpaste used averaged up to 59 percent to 65 percent for these children, who were at the age of maximal risk of developing dental fluorosis of the maxillary incisors. In Ripa’s review of dentifrice use and ingestion, he discounted the data of Simard et al because of the apparently long mean brushing time of five minutes and he did not have access to the more recent supportive data. Ripa’s calculated mean proportion of toothpaste ingested (27 percent) by children under age six and mean quantity of fluoride ingested (0.134 mg) are probably underestimates, therefore, especially among the youngest children. Only small percentages of young children have been found to rinse their mouths and many who do rinse with water may, due to inadequate control of their swallowing reflexes and lack of training, still ingest the majority of dentifrice used. Although dentifrice use and ingestion are quite variable among infants and one-year-olds, substantial proportions of these youngest children also ingest significant quantities of dentifrice.

Several reports provide data showing details of the frequency distribution of dentifrice use and ingestion and generally they show about 20 percent of the children’s quantities used and ingested to be well beyond the mean results most often quoted in the literature. The use of mean figures only can be misleading, and consideration should be given to both the mean and the distribution of results during policy-making discussions. Most authors have acknowledged this variation in toothpaste ingestion and recognized that some children could ingest more fluoride from dentifrice alone than the recommended daily total. "When combined with fluoride from other regular sources, such as beverages and food and dietary fluoride supplements, the total quantity of fluoride ingested increases and larger percentages of children are beyond the "optimal range" of fluoride intake." Ripa concluded that fluoride dentifrices were not the primary cause of the increase in the prevalence of fluorosis. It has been concluded, however, that ingestion of fluoride dentifrice is an "important part of total daily fluoride intake and some young children may be ingesting enough fluoride from dentifrice to cause dental fluorosis." Burt concluded that the use of a fluoride dentifrice by young children "has to be recognized as a risk factor for dental fluorosis." Although Ripa pointed out that the ingestion of fluoride toothpaste has generally not been identified as a risk factor for fluorosis in analytical studies, Pendrys and Rozier emphasized that the majority of the studies of fluorosis risk were not well designed for assessment of fluoride dentifrice as a risk factor, because of insufficient statistical power to draw such a conclusion. For example, most only asked whether fluoride toothpaste was used at an early age (yes/no) or...
when brushing was initiated, without regard to frequency of brushing, quantity of paste used and ingested, rinsing patterns, etc. The studies with more powerful designs, such as that by Osuji et al were more likely to report statistically significant effects of the early use of fluoride toothpaste on the prevalence of fluorosis. Several other recent studies have linked the early use of fluoride dentifrice with fluorosis. A recently concluded case-control study among 106 Iowa pediatric dental patients found that the number of years of use of fluoridated water and estimated total quantity of fluoride dentifrice used from birth to age eight (considering years of use, estimated amount used per brushing, and frequency of brushing) were independently associated with the risk of fluorosis. Future studies of the use and ingestion of dentifrice and risk factors for fluorosis must consider the details of fluoride ingestion from dentifrice and attempt to measure it. Also, as suggested by others, "use of higher concentration fluoride toothpastes by preschool children must be avoided." Further development and testing of lower concentration fluoride toothpastes are encouraged, and small quantities of dentifrice should be used with parental direction and supervision so that inappropriate "eating" of fluoride dentifrice is avoided. In these ways, use of fluoride dentifrice will continue to be an important caries preventive tool, while minimizing its role in the etiology of dental fluorosis.

REFERENCES

FLUORIDE CONCENTRATIONS OF INFANT FOODS AND DRINKS

Fluoride analyses of baby foods were carried out using a microdiffusion technique, which was found to be reproducible and accurate with less than 8 percent error. Analysis of 113 baby foods and drinks showed a wide range of fluoride concentrations: 0.01-0.31 mg F/kg for baby milk products; 0.04-0.72 mg F/kg for meat products; 0.04-0.70 mg F/kg for cereals; 0.03-0.45 mg F/kg for vegetable products; 0.03-0.07 mg F/kg for fruits; 0.02-0.25 mg F/kg for desserts, and 0.01-0.51 mg F/l for baby drinks. None of the baby foods and drinks contained fluoride of a sufficiently high concentration to be of concern or likely to contribute to enamel mottling, when used in the normal way.