Current Regulations and Recommendations Concerning Water Fluoridation, Fluoride Supplements, and Topical Fluoride Agents

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J DENT RES 1992 71: 1255
DOI: 10.1177/00220345920710052001

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>> Version of Record - May 1, 1992

What is This?
In recent years, an increase in the prevalence of dental fluorosis, mostly of the very mild to mild category, has been seen in the United States. This paper therefore discusses the safety of dental fluoride products, primarily with respect to the risk of dental fluorosis due to chronic ingestion of these products by pre-school children. No change is indicated in the optimal fluoride level (0.7 to 1.2 ppm) for water fluoridation. A reduction in the dosage of fluoride supplements is recommended for children aged from three to six years (14.5 to 22 kg body weight) residing in communities with less than 0.7 ppm F. Physicians, pharmacists, and dentists need to be better educated in correctly prescribing fluoride supplements; such prescriptions should be based on the fluoride concentration of the domestic water supply and the child's weight/height/age. No change is recommended in the concentration of fluoride used in dentifrices and mouthrinses. The US Food and Drug Administration should require more explicit labeling of fluoride products with regard to avoidance of ingestion, use of small amounts, and need for supervised use by pre-school children. The efficacy of water fluoridation, fluoride supplements, and topical fluoride agents has been amply documented elsewhere.


**Introduction.**

The effectiveness of water fluoridation in consistently lowering the level of caries prevalence has been documented in numerous surveys throughout the world (Murray and Rugg-Gunn, 1982; Newbrun, 1989b). Data concerning the safety of water fluoridation have been reviewed repeatedly by international, national, state, and local authorities (Commission of Inquiry, New Zealand, 1957; Royal Commissioner of Tasmania, 1968; WHO, 1970; Royal College of Physicians, 1976; National Academy of Sciences, 1977; Governor's Task Force on Fluorides, Michigan, 1979; Committee of Inquiry, Victoria, 1980; International Agency for Research on Cancer, 1982; Werdegard, 1985; Knox, 1985; Kaminsky et al., 1990; Working Party on the Effectiveness of Water Fluoridation, 1990; National Health and Medical Research Council, Canberra, 1991). In addition to these studies, scientists from the US Public Health Service have recently reviewed the results of 50 epidemiological studies as well as animal toxicity data (USDHHS, 1991). The conclusion of all of these reports has been uniform: there are no significant health risks associated with water fluoridation at an optimal level. Any risks to health from controlled water fluoridation, to which about 60% of the US population on public water supplies is exposed, have been impossible to detect in these epidemiological studies. Accidental ingestion of fluoride dental products (tablets, drops, rinses) occurs mostly in children younger than 6 years old, and is either asymptomatic or has mild and self-limited gastro-intestinal symptoms (Augenstein et al., 1991). Although acute toxic ingestion of fluoride occasionally occurs as a result of suicide attempts, industrial accidents, or human error (Abukurah et al., 1972; Baltazar et al., 1980; Lidbek et al., 1943; Yolken et al., 1976), it is extremely rare that dietary fluoride supplements or topical fluoride agents cause acute fatal poisoning.

Only three incidents of dental fluoride products causing fatalities have been reported. One case followed office topical therapy in which inappropriate agents and procedures were used and no adequate treatment was provided for management of the overdose (Church, 1976). The other two cases occurred from overdoses with fluoride tablets. In Brisbane, Australia, a 27-month-old boy died after ingesting an unknown number of fluoride tablets, each containing 0.5 mg of fluoride (Waldott, 1979). In the second case, a three-year-old (12.5 kg) child in Helfenberg, Austria, died after ingesting 200 tablets, each containing 1 mg of fluoride (Eichler et al., 1982). No fatalities from fluoride supplements have been recorded in the USA, where the maximum number of tablets that may be dispensed is 120, and containers must be equipped with a child-proof cap. When normal procedures are followed, the topical application of fluoride agents in the office or the self-application of fluoride agents in the home does not pose a risk of acute fatal toxicity. One additional case worth discussing is that of a 73-year-old man who, in a pharmacy, was mistakenly given a 20% stannous fluoride solution instead of water with which to swallow his antibiotic medication and subsequently died (Litovitz et al., 1990; Whitford, 1992). His death was not the result of using any fluoride-containing preparation available for office or home use. An 8% stannous fluoride concentration used for office application is usually prepared freshly, since it oxidizes on standing, and a 0.1% stannous fluoride rinse used at home is also prepared by dissolution of individually wrapped tablets immediately before use.

Nevertheless, some concern has been expressed that, with the wide array of both prescription and over-the-counter fluoride products now being marketed in the USA, the total fluoride intake has increased. There is no indication that chronic low-level exposure to fluoride presents a problem in organ systems (gastro-intestinal, genito-urinary, respiratory) of normal individuals (USDHHS, 1991), nor has skeletal fluorosis been detected in the USA. The prevalence of dental fluorosis, on the other hand, has increased noticeably in non-fluoridated areas and to a lesser extent in optimally fluoridated areas (USDHHS, 1991; Leverett, 1986; Pendrys, 1991a; Pendrys and Stamm, 1990; Szpunar and Burt, 1987). Accordingly, the focus of this paper will be the appropriateness of current dosages and concentrations of fluoride products used by or on young children. Without getting into the dispute over whether dental fluorosis is a minor cosmetic problem (Horowitz, 1989) or an early toxicological sign (Fejerskov et al., 1988), we need to put the whole issue of dental fluorosis into perspective. Most children living in either optimally fluoridated or sub-optimally fluoridated areas show no dental fluorosis at all, or only the mildest form of the condition. Moderate to severe fluorosis with brown spots or pitting affects 1.3% of US children (Brunelle, 1989).

**Water fluoridation.**

The World Health Organization (1984) has set a maximum concentration of 1.5 ppm fluoride in drinking water to avoid dental fluorosis. In the United States, the optimal concentration of fluoride recommended for caries prevention is between 0.7 and...
1.2 ppm, depending upon the annual average maximum daily air temperature in the community. The US Environmental Protection Agency (EPA) has established a maximum primary contaminant level (MCL) of 4 ppm fluoride for drinking water, which was based on the avoidance of skeletal, but not dental, fluorosis (US EPA, 1986). A secondary MCL of 2 ppm fluoride was set to protect against moderate to severe dental fluorosis. The optimal concentration of fluoride for drinking water is that level which offers minimal risk of dental fluorosis while providing significant protection against caries. The range of 0.7 to 1.2 ppm, which was based on the extensive epidemiological studies of H. Trendley Dean and others during the late 1930’s (Dean, 1946), may not apply in all countries. For example, a lower maximum level may be required in countries with very hot, dry climates where the population does more physical work, and consequently has increased sweat loss and greater water intake (Brouwer et al., 1988). However, in the United States it is not necessary to change the recommendations for the presently accepted optimal level, as has been proposed (Leverett, 1982, 1991). These levels have been found quite safe and cause a mean prevalence of dental fluorosis of 22% in children ages 7 through 17, mostly limited to questionable or very mild categories (Brunelle, 1989). Any reduction in the currently accepted optimal level would inevitably result in an increase of dental caries.

Fluoride supplements.

A recent report on Scottish children found no significant differences in the prevalence of enamel fluorosis between those who had started fluoride supplementation at birth and those who had commenced as late as 7 years of age, or who had never taken any such supplement (Stephen et al., 1991). However, in most studies the use of fluoride supplements has been identified as the major risk factor for dental fluorosis (Rozier, 1991) (Table 1). Accordingly, the current fluoride prescription practices must be closely examined. It is generally agreed that fluoride supplements, in the form of tablets, drops, or lozenges, reduce dental decay if taken on a regular basis throughout early childhood (Driscoll, 1974; Wei, 1986). In order to benefit the deciduous as well as the permanent teeth, fluoride supplements should be started no later than 5 to 6 months after birth (Picton, 1991), although most authorities recommend starting at birth. Occasionally, other factors—such as prematurity, very low birth weight, or substantial medical problems—may dictate a delay in starting for the infant. Many different dosage schedules, mostly related to a child’s age, have been proposed and are currently being used throughout the world (Marthaler, 1992; New brun, 1978; Stephen et al., 1991; Wei et al., 1977). The Council on Dental Therapeutics (CDT) of the American Dental Association originally recommended using bottled water containing 1 ppm fluoride to prepare infant formulas and other foods for children under two years of age (ADA, 1958). For children two to three years of age, 1 mg of fluoride was recommended to be taken on alternate days, and for those over three years of age, daily ingestion of 1 mg fluoride was recommended. This dosage applied to those children residing in communities with 0 to 0.2 ppm of fluoride in the natural water supply. The amount of fluoride supplement was adjusted downward by 10% for each 0.1 ppm of fluoride in the drinking water, so that at 0.2 ppm fluoride in the drinking water, 0.8 mg of fluoride was recommended daily; at 0.4 ppm fluoride, 0.6 mg was recommended daily; and at 0.6 ppm fluoride, 0.4 mg was recommended daily. This was not a very practical regimen to follow; fluoride drops had to be used because no tablets containing these fractional amounts (0.4, 0.6, 0.8 mg) were marketed, and the recommendation was therefore largely ignored. In the 1975-76 edition of Accepted Dental Remedies, the CDT suggested a dosage of 0.25 mg of fluoride per day for the period from birth to age two years as a possible satisfactory alternative. Until 1979, the American Academy of Pediatrics used a different dosage schedule, consisting of 0.5 mg of fluoride from birth to three years of age and 1 mg of fluoride daily after three years of age. This dosage schedule was revised downward and adjusted for the concentrations of fluoride in the drinking water. This schedule was a compromise between precision of dosage and practicality (AAP Committee on Nutrition, 1979).

Chronologically, the “window of vulnerability” to dental fluorosis involving the permanent anterior teeth lies somewhere between birth and age six years. Therefore, it is the dosage during this age period that needs to be most carefully scrutinized. Weight-based dosing of fluoride supplements is more appropriate than age-based dosing. Dosage can also be related to length (height), which in some situations may be more practical to measure (Lubitz et al., 1988). Assuming a threshold dose for enamel fluorosis of 0.05 mg/kg of body weight, the total amount of fluoride that should not be exceeded and the current dosage of fluoride supplements are plotted against age/body weight/length (Fig. 1). This value of 0.05 mg F/kg body weight is at the lower end of a range from 0.04 to 0.07 mg F/kg, which has been reported in the literature as an optimal or threshold intake (McClure, 1943; Farkas and Farkas, 1974; Toth, 1975; Forsman, 1977; Ophaug et al., 1980; Baelum et al., 1987). These literature values are generally soft data, based on “guesstimates” rather than on carefully controlled clinical trials. Despite what he terms its “dubious genesis”, Burt (1992) considers the 0.05 to 0.07 mg/kg range a useful guideline.

As Fig. 1 shows, the currently used supplemental dosage for ages three to six years exceeds or closely approximates the total maximal intake of fluoride recommended to limit dental fluorosis. It allows little leeway for additional intake from the diet, which could be significant for children living in a non-fluoridated community surrounded by predominantly fluoridated communities. Nor does it allow for unintentional ingestion of topical fluoride agents, as discussed further below. Based on the data

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**TABLE 1**

RISK FACTORS FOR DENTAL FLUOROSIS

<table>
<thead>
<tr>
<th>Risk Factor</th>
<th>Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early use of supplements, formula use, low birth weight</td>
<td>Forsman, 1977</td>
</tr>
<tr>
<td>Supplements</td>
<td>Pendrys and Katz, 1989</td>
</tr>
<tr>
<td>Supplements, dentifrice use, formula use</td>
<td>Leverett et al., 1988</td>
</tr>
<tr>
<td>Supplements</td>
<td>Kumar et al., 1989</td>
</tr>
<tr>
<td>Supplements</td>
<td>Woolfolk et al., 1989</td>
</tr>
<tr>
<td>Supplements</td>
<td>Ismail et al., 1990</td>
</tr>
<tr>
<td>Supplements, gels, rinses</td>
<td>Bohaty et al., 1989</td>
</tr>
<tr>
<td>Prolonged formula use, early fluoride dentifrice use</td>
<td>Osuji et al., 1988</td>
</tr>
<tr>
<td>No consistent factor</td>
<td>Williams and Zwemer, 1990</td>
</tr>
<tr>
<td>Supplements</td>
<td>Riordan and Banks, 1991</td>
</tr>
</tbody>
</table>

*80% of children living in optimal fluoride city reported using supplements.*
in Fig. 1, it might also seem prudent to reduce the dosage to less than 0.25 mg fluoride during the first six months of life, as has been suggested (Wei et al., 1977). However, during this neonatal period very little fluoride is obtained from the diet, since breast milk contains only about 0.004 ppm F, and manufacturers of milk-based formulas have taken steps to reduce the fluoride concentration to negligible levels (Johnson and Bawden, 1987). Only a few infants who must use soy-based formulas and take a fluoride supplement of 0.25 mg/day would exceed the optimum (McKnight-Hanes et al., 1988). Since no teeth are erupted at this age, exposure to topical fluorides is unlikely.

The establishment of 1.0 ppm F as the recommended optimum level (adjusted to between 0.7 and 1.2 ppm according to climate) was based on extensive epidemiological data. The recommendation of 1.0 mg F supplements for children three years and older in non-fluoridated communities was based on estimated fluid intake, which may vary from day to day but is relatively constant on a weekly basis and is directly related to mean temperature. These norms for optimal dosage of fluoride, in terms of total intake as well as intake from drinking water, have been criticized as being “established empirically” (Leverett, 1986). The dictionary defines empirical as based on observation or experiment or deriving knowledge from experience. I see nothing wrong with empirically derived recommendations, especially since testing various fluoride supplemental dosage schedules for efficacy in caries prevention and effect on fluorosis of the permanent teeth requires 8- to 10-year-long clinical trials with a high degree of continuous compliance. Few granting agencies, if any, are willing to support such long-term randomized clinical trials as are demanded by the purists. When the Committee on Nutrition of the AAP (1978) revised the dosage schedule, it was done in response to clinical observations of moderate fluorosis of the enamel in a few children, and to the need to achieve a closer parallel with changes in body weight in infancy and childhood. The downward adjustment of fluoride supplemental dosages now proposed for children weighing between 14.5 and 22 kg (ages three to six years) is based on the same rationale and is, indeed, empirical. Unless we wait another ten years for the results of controlled clinical trials, the participants at this symposium and Federal agencies will have to continue to make such empirical decisions.

Because of the declining caries prevalence and the widespread use of topical fluoride agents, both in the office and at home, it has been suggested that fluoride supplements are no longer needed as a public health measure (Szpunar and Burt, 1992). This is unacceptable on the following grounds. In some regions of the United States, a high proportion of the population is living in optimally fluoridated communities, so that the minority of the population where the water fluoride is suboptimal may be getting significant amounts of fluoride from food and beverage products processed in the optimally fluoridated areas, the so-called “halo effect”. Studies in Canada have documented

### Table 2

<table>
<thead>
<tr>
<th>Weight (kg)</th>
<th>Age (years)</th>
<th>Concentration of Fluoride in Drinking Water (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>&lt;0.3</td>
</tr>
<tr>
<td>3.4 - 12.4</td>
<td>Birth to 2</td>
<td>0.25</td>
</tr>
<tr>
<td>12.4 - 16.4</td>
<td>2 to 4</td>
<td>0.50</td>
</tr>
<tr>
<td>16.4 - 21.5</td>
<td>4 to 6</td>
<td>0.75</td>
</tr>
<tr>
<td>&gt;21.5</td>
<td>&gt;6</td>
<td>1.00</td>
</tr>
</tbody>
</table>

\(^{2.2 \text{ mg sodium fluoride contains } 1 \text{ mg fluoride.}}\)
Fig. 3—Topical fluoride agents for professional or home use, showing the range of fluoride concentrations in dentifrices, mouthrinses, gels, solutions, and prophylaxis pastes, as well as a listing of products available in the United States in each category.

Recommendations.

(1) For children weighing from 14.5 to 21.5 kg (from three to six years of age) and residing in communities with less than 0.7 ppm fluoride in the drinking water, lower the fluoride supplement dosage as shown in Table 2. This proposed schedule coincides with what has been used in Switzerland since 1966 (Marthaler, 1992).

(2) Test the effectiveness of controlled-release fluoride tablets that contain small amounts of available fluoride on the surface for immediate intra-oral effect. The bulk of the fluoride, however, should be provided in a slow-release form to avoid a high plasma fluoride peak, as occurs within the first hour of ingestion when a fluoride supplement is taken as a single bolus. A less practical alternative to the use of controlled-release fluoride tablets is the option of taking fluoride supplements in divided portions, as tested by Driscoll et al. (1977). Tests on mice have shown a significantly lower degree of incisal fluorosis when the daily dose was given in three or five portions instead of one (Ruzicka et al., 1981). Unfortunately, children are less compliant than mice and are unlikely to follow a divided-dose schedule, since long-term compliance on a single-dose schedule has been poor (Newbrun, 1980; Widenheim, 1982).

(3) Educate dentists, pharmacists, and physicians (especially family practitioners and pediatricians, who are usually the first to prescribe fluoride supplements during the neonatal and early childhood periods) concerning the correct dosage schedule based upon weight/height/age and fluoride level in the child’s water supply. Various surveys of children residing in optimally fluo-

### TABLE 3

**FOOD AND DRUG ADMINISTRATION PROPOSED RULES FOR ACTIVE INGREDIENTS IN FLUORIDE DENTIFRICES**

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>NaF</td>
<td>0.188 to 0.254% with an available fluoride ion concentration of ≥ 650 ppm</td>
</tr>
<tr>
<td>MFP</td>
<td>0.564 to 0.884% with an available fluoride ion concentration (consisting of PO₄³⁻ and F⁻ combined) of ≥ 800 ppm</td>
</tr>
<tr>
<td>SnF₂</td>
<td>0.351 to 0.474% with an available fluoride ion concentration of ≥ 700 ppm for products containing abrasives other than Ca₃P₂O₇</td>
</tr>
<tr>
<td>SnF₂</td>
<td>0.351 to 0.474% with an available fluoride ion concentration of ≥ 290 ppm for products containing the abrasive Ca₃P₂O₇</td>
</tr>
</tbody>
</table>
supplementation during weaning in fluoridated communities is that it is by food. The amount of fluoride ingested has occurred without proper fluoride prescription writing should become a part of medical school and pediatric residency training. Since pharmacists form the public’s last line of defense against improper prescriptions, they too need to be educated concerning correct fluoride dosages.

4. Use weight/height, rather than age, as the basis for fluoride supplementation, since it allows for individual variation in size. A novel method of dosage by use of a color-coded measuring tape has been developed for pediatric emergency resuscitation and may be suitable for home use (Broselow, personal communication).

5. Cease the practice of providing supplemental fluoride during breast feeding of children residing in optimally fluoridated communities. Some consider such supplementation appropriate because of the low levels of fluoride in breast milk. However, the reduction in caries observed clinically in thousands of children living in naturally fluoridated communities has occurred without supplementation of the children’s diets during breast-feeding (Newbrun, 1991). Infant feeding practices vary considerably throughout the United States according to regional, ethnic, socio-economic, and urban-suburban factors. The weaning pattern is largely an early one, i.e., before six months of age; more than 90% of children receive some semi-solid food by the age of four months (Fomon, 1987; Wharton, 1989). The amount of fluoride obtained from the drinking water after weaning appears to be sufficient. Another reason for not starting fluoride supplementation during breast feeding in optimally fluoridated communities is that it is more likely to lead to continued and inappropriate use of supplements after weaning.

Table 4: Children’s Fluoride Dentifrices: International Status

<table>
<thead>
<tr>
<th>Country</th>
<th>Product</th>
<th>Active Ingredient</th>
<th>Fluoride (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td>Blendax Blendi</td>
<td>NaF</td>
<td>250</td>
</tr>
<tr>
<td>Belgium</td>
<td>Blendax Blendi</td>
<td>NaF</td>
<td>250</td>
</tr>
<tr>
<td>Germany</td>
<td>Blendax Blendi</td>
<td>NaF</td>
<td>250</td>
</tr>
<tr>
<td></td>
<td>Colgate Milk</td>
<td>MFP</td>
<td>400</td>
</tr>
<tr>
<td>Great Britain</td>
<td>Boots Children’s Gel</td>
<td>MFP</td>
<td>250</td>
</tr>
<tr>
<td></td>
<td>Boots Tom &amp; Jerry</td>
<td>MFP</td>
<td>500</td>
</tr>
<tr>
<td></td>
<td>Colgate Junior</td>
<td>MFP</td>
<td>400</td>
</tr>
<tr>
<td></td>
<td>SmithKline, Beecham</td>
<td>MFP</td>
<td>500</td>
</tr>
<tr>
<td></td>
<td>Milk Teeth</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Netherlands</td>
<td>Elmex Peutertandpasta</td>
<td>Amine fluoride</td>
<td>250</td>
</tr>
<tr>
<td></td>
<td>Prodent Peuterpaste</td>
<td>NaF &amp; MFP</td>
<td>250</td>
</tr>
<tr>
<td>New Zealand</td>
<td>Colgate Junior</td>
<td>MFP</td>
<td>400</td>
</tr>
<tr>
<td>Switzerland</td>
<td>Blendax Blendi</td>
<td>NaF</td>
<td>250</td>
</tr>
<tr>
<td></td>
<td>Droggerei Verband</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td></td>
<td>Elmex</td>
<td>Amine fluoride</td>
<td>250</td>
</tr>
</tbody>
</table>

Topical fluoride agents.

The concentration of fluoride used in most agents for caries prevention at home and in the dental office ranges from 230 ppm in OTC fluoride mouthrinses to 19,500 ppm in 8% SnF₂ solutions, an almost 100-fold range (Fig. 3). One lower-concentration fluoride rinse (125 ppm in Listermint Fluoride) and one higher-concentration fluoride paste (20,000 ppm in Ziroxide) are marketed. If one includes fluoride agents used for desensitizing dentin, the concentration is even greater, up to 151,000 ppm F in a NaF/glycerine/kaolin paste (Fig. 4). However, since desensitizing pastes are rarely used on children under six years of age, we can confine our consideration to the caries-preventive agents. The office fluoride agents are usually applied only once or twice per year. If the guidelines recommended for the reduction of unintentional fluoride ingestion during professional application (Lecompte, 1987; Horowitz and Heifetz, 1986) are carefully adhered to, such therapy is unlikely to cause dental fluorosis. Accordingly, the main concern should be with those products that are used once, twice, or thrice per day or on a weekly basis, and particularly those that are available over the counter with no professional supervision or guidance as to their use. The concentration of fluoride in dentifrices, mouthrinses, and gels for home use is regulated by the Food and Drug Administration. For dentifrices, the agency has proposed a range of concentrations from 850 to 1150 ppm total fluoride (USFDA, 1988). Since the availability of fluoride ion in concentrations that are safe and effective is the most important consideration, the agency has further specified minimal fluoride ion concentrations that must be available in dentifrices, depending on the active ingredient (Table 3). Although the agency has approved OTC marketing of a fluoride dentifrice containing 1500 ppm total fluoride under a New Drug Application, other dentifrices containing in excess of the proposed range cannot be marketed without an approved application. Guidelines for the acceptance of fluoride-containing dentifrices by the CDT of the American Dental Association do not specify the concentrations of fluoride to be used, but no fluoride products for home use should contain in excess of 120 mg fluoride (ADA, 1984).
Many prophylaxis pastes for professional use contain fluoride in the range of 4000 to 20,000 ppm (Fig. 3). Except for some Scandinavian studies (Axelsson and Lindhe, 1974, 1975; Axelsson et al., 1976; Poulsen et al., 1976) involving frequent (every two to four weeks) professional tooth-cleaning with a fluoride-containing paste (2200 ppm), there are no data documenting efficacy from the annual or semiannual use of such products. Although there is little likelihood of chronic ingestion of fluoride from these agents, the wide range of their fluoride content is without any basis. A maximum fluoride content of 12,300 ppm, equal to that used in office APF gels, may suffice, although clinical trials are needed for efficacy to be documented. The US Food and Drug Administration should require manufacturers of such pastes to provide justification for their fluoride content.

**Fluoride dentifrices.**

More than 95% of all toothpastes sold in the United States contain some form of fluoride, and toothbrushing starts at an early age. The growing literature on dentifrice retention and ingestion has recently been reviewed by Rips (1991), who estimated that, for children under age six, the average retention was 27% of the amount placed on the brush. Assuming a junior-sized toothbrush holding 0.5 g of dentifrice at a concentration of 1000 ppm F, the average retention would be 0.134 mg F. Since most children brush twice daily, this would contribute about 0.268 mg to the total F intake. Similarly, an intake of 0.3 mg F from dentifrices has been estimated for two-year-old children (Pendrys and Stamm, 1990).

### TABLE 5

<table>
<thead>
<tr>
<th>Study</th>
<th>Fluoride, ppm (agent)</th>
<th>Duration, years</th>
<th>Supervised Use</th>
<th>Diagnostic Radiographs</th>
<th>Fluoride Dose/Response</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reed (1973)</td>
<td>0/250/500/1000 (NaF)</td>
<td>2</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>Used Ca₃P₂O₇ abrasive, F only partly available</td>
</tr>
<tr>
<td>Forsman (1974)</td>
<td>0/250/1000 (MFP &amp; NaF)</td>
<td>2</td>
<td>-</td>
<td>+</td>
<td>+/-</td>
<td>Supervised use of 0.2% NaF rinse biweekly, relatively low caries increments</td>
</tr>
<tr>
<td>Gerdin (1974)</td>
<td>250/1000 (NaF)</td>
<td>2</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>Low-F dentifrice had a low pH, 5.5</td>
</tr>
<tr>
<td>Hodge et al. (1980)</td>
<td>0/1000/1450 (MFP &amp; NaF)</td>
<td>3</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>Girls demonstrated efficacy more dramatically than boys and had oral hygiene</td>
</tr>
<tr>
<td>better</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Koch et al. (1982)</td>
<td>250/1000 (MFP &amp; NaF)</td>
<td>3</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>Insufficient sample size, chance of not detecting differences</td>
</tr>
<tr>
<td>Buhe et al. (1984)</td>
<td>0/1000/1500 (MFP)</td>
<td>3</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>Increasing F level resulted in increased efficacy</td>
</tr>
<tr>
<td>Mitropoulos et al. (1984)</td>
<td>250/1000 (MFP)</td>
<td>2.7</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>Reducing F level resulted in lower efficacy</td>
</tr>
<tr>
<td>Diodati et al. (1986)</td>
<td>1000/1450/2000 (MFP &amp; NaF)</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>Increased efficacy at higher F levels, no significant difference between the higher levels</td>
</tr>
<tr>
<td>Stephen et al. (1988)</td>
<td>1000/1500/2500 (MFP)</td>
<td>3</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>Increased efficacy at higher F levels</td>
</tr>
<tr>
<td>Lu et al. (1987)</td>
<td>1100/2800 (NaF)</td>
<td>3</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>Increased efficacy at higher NaF levels</td>
</tr>
<tr>
<td>Rips et al. (1988)</td>
<td>1000/2500 (MFP &amp; NaF)</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Poor compliance, dentifrice distasteful, high withdrawal rate</td>
</tr>
<tr>
<td>Conti et al. (1988)</td>
<td>1000/1500 (MFP)</td>
<td>3</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>Dose/response effect shown in a suboptimal F area</td>
</tr>
<tr>
<td>Fogels et al. (1988)</td>
<td>1000/1500 (MFP)</td>
<td>3</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>Dose/response effect shown in an optimal F area</td>
</tr>
<tr>
<td>Koch et al. (1990)</td>
<td>250/1000 (MFP &amp; NaF)</td>
<td>3</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>NaF superior to MFP, biphosphonates do not interfere with F effect</td>
</tr>
<tr>
<td>Winter et al. (1989)</td>
<td>550/1050 (NaF &amp; MFP)</td>
<td>3</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>More caries-free children with higher-level F paste</td>
</tr>
</tbody>
</table>

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Accordingly, some dentists have advocated lowering the concentration of fluoride for children's toothpaste (Whitford, 1992; Whitford et al., 1987; Beltrán and Szpunar, 1988). Low-concentration (250, 400, and 500 ppm) fluoride toothpastes are available in Austria, Belgium, Czechoslovakia, Finland, France, Germany, Israel, Luxembourg, The Netherlands, New Zealand, Portugal, Sweden, Switzerland, and the United Kingdom (Table 4). In several of these countries, dentifrices of relatively higher fluoride concentration (1500 and 2000 ppm) are more commonly used by adults, and therefore there is a greater need for such children's pastes. However, dentifrices with 2000 ppm fluoride are not marketed in the USA, and their approval would require a New Drug Application and clinical trials. Actually, the available fluoride ion concentration in the original Crest toothpaste was only about 260 ppm, but the total F content was 1000 ppm, as in most current commercial brands. I cannot recommend the introduction of such low-concentration fluoride dentifrices, for two reasons. First, the dentifrice/fluorosis relationship is unconvincing. During the past ten years, there have been ten independent studies seeking an association between the use of fluoride dentifrice and the prevalence of fluorosis (Ripa, 1991). Nine found no such association; granted, most of these studies lacked the large numbers necessary to allow adequate power to demonstrate such an association (Pendry, 1991b). One study (Osuji et al., 1988) that found an association used a different fluorosis index, in which scores of 1 or 2 are assigned to teeth with opacity-accented perikymata lines that would not even be considered in the questionable category by Dean's Index. Second, the preponderance of the dose/response efficacy data on fluoride dentifrices indicates that a lower fluoride concentration provides less caries protection (Table 5). Of 15 studies comparing the efficacy of fluoride dentifrices at different fluoride concentrations, ten have demonstrated a dose/response relationship, one showed a questionable relationship, and four showed no relationship. Generally, the studies that failed to show a relationship did not compare identical formulations at different concentrations (e.g., dentifrices differed in pH [Gerding, 1974] or active agent [Winter et al., 1989]), used insufficient sample size (Koch et al., 1982), or had problems with compliance (Ripa et al., 1988).

Based on the currently available data, therefore, almost all of the studies designed to test the dentifrice/fluorosis relationship have failed to demonstrate an association, but they have also failed to rule one out (Pendry and Stamm, 1990). However, in Scotland, in a follow-up of a study originally aimed at testing a high-fluoride dentifrice (2400 ppm) in a non-fluoridated community, no significant hypoplasia or fluorosis was found in the younger siblings who had used this dentifrice when compared with a control population using a placebo dentifrice without fluoride (Houwink and Wagg, 1979).

On the other hand, the findings of the dose/response relationship clearly lead to the conclusion that lowering the fluoride concentration of dentifrices will result in an increase in caries. For these reasons, I cannot recommend lowering the concentration of fluoride in children's dentifrices unless more efficacious fluoride-delivery systems become available for dentifrices.

Since most children brush their teeth once or twice daily, and almost 99% of the dentifrices sold in the United States contain fluoride, it is not possible to compare fluorosis in children using fluoride-containing toothpaste with that in those using a non-fluoride-containing toothpaste. Accordingly, several studies have compared the prevalence of fluorosis with the age at which the children were reported to have started toothbrushing. Studies in Canada (Osuji et al., 1988) and in England (Milsom and Mitropoulos, 1990) show a significant relationship between fluorosis and the age at which parents claim to have started brushing their children's teeth.

Several problems are readily apparent in evaluation of the various surveys that have measured the prevalence of fluorosis and attempted to identify the factor(s) responsible. (1) Different indices have been used, such as the Dental Fluorosis Index (Dean, 1942), the Tooth Surface Index of Fluorosis or TSIF (Horowitz et al., 1984), the Developmental Defects of Enamel or DDE Index (FDI, 1982), and the Tooth Fluorosis Index or TFI developed by Thylstrup and Fejerskov (1978)—all with different criteria for scoring and different sensitivity. Accordingly, the findings are not directly comparable.

(2) Investigators have postulated that one or several factors (dentifrice, gel, supplement, socio-economic status, etc.) may be related to fluorosis, and in doing so have deliberately excluded some children from their analyses (e.g., excluding children who use supplements in surveys of age at which toothbrushing commenced). Thus, in attempting to avoid confounding, they may have overlooked a relatively more significant factor.

(3) Parents have been asked to fill out questionnaires concerning the age at which their children started toothbrushing and their use of fluoride and/or vitamin supplements. Except for identifying their social class, most questionnaires depend on the accuracy of parents' recall of data, which is inherently weak, since the event occurred five or more years previously. Also, parents want to give the impression that they are caring and responsible about their children's dental health, and this may bias their response. How else can one explain the difference between two British surveys, one reporting 75% of children as having started brushing by 18 months of age (Dowell, 1981), whereas another found that only 43% had begun brushing by two years of age (Milsom and Mitropoulos, 1990)?

(4) Investigators have attempted to quantitate how much fluoride is ingested by children during toothbrushing, since the amount habitually swallowed contributes to the total fluoride intake. Such studies should simulate real home-use conditions. In one such study, Simard et al. (1989) replicated whether the parent or child did the brushing, the size toothbrush used, how much paste was spread on the brush, and whether the child expectorated after brushing—all of which are important determinants of how much fluoride is actually swallowed. However, an additional determinant—length of time the child brushes—was based on a five-minute brushing time. Since most children spend less than one minute brushing (Newbrun, 1989a), it is not surprising that the values in this study for fluoride ingestion from brushing were inflated.
Recommendations.

(1) In the currently available dentifrices for children, the concentration of fluoride should not be lowered below 1000 ppm.

(2) Parents should brush pre-school children's teeth until they can do it properly by themselves.

(3) Parents should apply the dentifrice to the toothbrushes of pre-school children until they can do it properly by themselves.

(4) Parents of pre-school children should supervise their toothbrushing activity, and in such households dentifices should be stored out of the reach of toddlers.

(5) Pre-school children should use a child's-size toothbrush.

(6) Only a pea-sized amount of dentifrice should be applied to the toothbrush bristles.

(7) Children should be taught to rinse thoroughly after toothbrushing.

(8) Manufacturers should be required to label fluoride products with the specific fluoride concentration and a warning that children under six years of age should use only a pea-sized portion, should spit out after brushing, should avoid swallowing the paste, and should rinse thoroughly afterward.

(9) Manufacturers should be encouraged to market toothpastes for young children in tubs with a narrow orifice or a pump designed to release a unit dose appropriate for a preschooler.

(10) The Council on Dental Therapeutics, in addition to the FDA, should take a stand regarding labeling requirements of many products requesting acceptance. In 1987, Council accepted Extra Strength Aim based on clinical efficacy (Conti et al., 1988; Fogels et al., 1988). In doing so, it disregarded advice from its consultants, who wanted much more specific labeling information concerning the use of this product and the specific warning that it was contra-indicated for use by pre-school children. In spite of promises, this manufacturer has not changed the labeling.

Comment.

It has been suggested that reducing the amount of dentifrice to a pea-sized portion when brushing the teeth of pre-school children decreases the amount of fluoride that is applied and, therefore, could be less effective in caries prevention (similar to reducing the fluoride concentration in the paste but keeping the volume the same). I do not think that this is an appropriate analogy. The efficacy of dentifices in the prevention of caries has been demonstrated in children who were usually aged 8 to 14 years and thus had more teeth, larger mouths, and more saliva than pre-school children (Watanabe and Dawes, 1990). In pre-school children, a pea-sized portion would, therefore, remain more concentrated, and presumably efficacy would not be compromised as it might be in adolescents or adults.

Fluoride mouthrinses.

Fluoride mouthrinses are widely used at home and in school-supervised programs. These products received approval by the FDA in 1974 (USFDA, 1974) and acceptance by the CDT in 1975 (ADA, 1975). Originally they were available only on a prescription basis as a 0.05% NaF rinse (230 ppm F) used daily and a 0.2% NaF rinse (920 ppm F) used weekly or fortnightly. Subsequently, several low-fluoride-concentration products (0.05% NaF rinse, 0.1% SnF₂ rinse, APF rinse containing 0.2% F, and a 0.1% SnF₂ gel) were permitted to be sold on an over-the-counter basis (USFDA, 1983). In addition, a prescription-only daily rinse-supplement consisting of 0.44% APF and an OTC 0.025% NaF rinse intended for twice-daily use are marketed. The latter, however, has not received CDT acceptance because its efficacy was insufficiently documented. The efficacy of fluoride mouthrinses in caries reduction varies with the concentration used, the compliance (i.e., frequency of use), and whether the user is living in a fluoride-deficient or optimally fluoridated community. Generally, a caries reduction of about 30% has been reported when 10 mL of rinse was used for 60 s.

Undoubtedly, some fluoride from these mouthrinses will be ingested. Two reports have found some relationship between mouthrinsing and fluorosis (Bohaty et al., 1989; Szpunar and Burt, 1988), and two reports found no such relationship (Osuji et al., 1988; Szpunar and Burt, 1990). Since most children are first exposed to fluoride mouthrinsing in school-based programs at five to six years of age, they are generally beyond the “window of vulnerability” discussed previously. Accordingly, fluoride mouthrinses do not appear to be a major factor contributing to the risk of dental fluorosis. Nevertheless, because several of these agents are available OTC, and some children could use them at an early age, prudent guidelines on expectorating and not swallowing such products should be clearly displayed on the container.

Recommendations.

(1) Fluoride mouthrinses are an appropriate caries-preventive procedure for patients with a moderate or intermediate level of caries activity.

(2) Fluoride mouthrinses should not be used by pre-school-aged children.

(3) Kindergarten children, under supervision, should rinse with 5 mL of solution for 30 s instead of 10 mL of solution for 60 s.

(4) All containers should clearly display legible instructions that the user should expectorate and avoid swallowing the rinse, and that the rinse should not be used by children under six years of age.

Acknowledgments.

The author is indebted to Drs. Burt, Marthaler, Ripa, Rozier, and Szpunar for making available pre-publication copies of their manuscripts, and to Ms. Evangeline Leash for editing this manuscript.

REFERENCES


Axelsson P, Lindhe J (1975). Effect of fluoride on gingivitis and dental...


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