# Total Fluoride Intake and Implications for Dietary Fluoride Supplementation

**Steven M. Levy, DDS, MPH; Nupur Guha-Chowdhury, MDS, PhD**

## Abstract

*This paper reviews the history and validity of recommended "optimal" levels of systemic fluoride intake and the available information on levels of fluoride intake in young children from foods and beverages (including water), dentifrices, dietary fluoride supplements, mouthrinses, and gels. Most of the studies emphasize the substantial variation in ingestion among individuals. Often, a substantial proportion of individuals received fluoride well beyond the mean exposure reported in the study. Limitations in the existing data make it difficult to determine the total distribution of fluoride intake from all sources. Therefore, hypothetical combinations of possible daily fluoride intake from the three main sources (diet, dentifrices, and supplements) are presented for those aged 6, 12, 24, and 36 months, with associated mean intake per kg body weight. Findings suggest that some children exceed the "optimal" level of fluoride intake from single sources alone, while others can from a combination of sources. Moreover, if current recommended "optimal" levels, which have been derived on an empirical basis, are actually lower than what has been quoted in the literature, then more children could be ingesting excessive amounts of fluoride, which could increase their risk of developing objectionable dental fluorosis. The variation and complexity of fluoride ingestion from all sources should be considered in the evaluation of recommendations for use of dietary fluoride supplements. [J Public Health Dent 1999;59(4):211-23]*

*Key Words: fluoride, ingestion, intake, exposure, dietary, supplements.*

The cariostatic effect of fluoride now is considered to be due mainly to its presence in oral fluids posteruptively via its ability to decrease the rate of enamel demineralization and enhance remineralization of early carious lesions (1-3). At lower levels of intake, fluoride confers caries protection (1-3), while excessive intake during the period of enamel formation can cause enamel fluorosis (4-6). The concentration of fluoride in the oral fluids is determined mainly by oral exposure to fluoride in food and beverages (including water), dentifrice, and other fluoride-containing agents (7,8). Systemic intake of fluoride from any of these sources results in the absorption of fluoride and its distribution to tissues, including the salivary glands, from where it is secreted back into the mouth (8,9). Therefore, all sources of systemic fluoride are of interest.

When considering recommendations for "optimal" fluoride use with goals of maximizing dental caries prevention while minimizing objectionable dental fluorosis, data from controlled, longitudinal, clinical trials of precisely determined levels of fluoride ingestion, dental caries, and fluorosis are desirable (10). However, no such studies have been conducted due to logistical, ethical, and financial constraints; thus, the currently available information has been obtained from less comprehensive studies (10). The level of fluoride intake sufficient to confer caries protection and beyond which dental fluorosis may occur (optimal level) is, therefore, not known accurately. Many aspects concerning fluoride, including fluoride intake and its relationship with caries and dental fluorosis, have been reviewed at a number of recent meetings (11-15) and in other publications (16-18). In this paper, recommended "optimal" levels of fluoride intake are discussed and the available information on levels of fluoride intake in children from food and beverages (including water) as well as from fluoride dentifrices, dietary fluoride supplements, mouthrinses, and gels are highlighted and updated.

## Optimal Levels of Fluoride Intake

It is well established that enamel fluorosis can occur only while the enamel is forming (4,5). Generally, it also has been agreed that to avoid an undesirable degree of dental fluorosis the daily fluoride intake in children definitely should not exceed 0.10 mg/kg of body weight (bw) (19-21). This threshold value of intake above which dental fluorosis occurs was derived from McClure's assessment of levels of fluoride intake from food and beverages (including water) by children in 1943 when fluoride dentifrices, rinses, gels, and supplements were not available (22). Using rough estimates of type and quantity of food and beverages (including water) consumed and less sensitive techniques than the fluoride electrode to measure fluoride content, McClure estimated that children aged 1–12 years living in fluoridated areas (1 ppm) received 0.16–0.103 mg F/kg bw from food and water alone, with most in the lower to middle part of this range, and the fluoride intake rarely exceeded 0.10 mg/kg bw. At these levels of dietary fluoride intake and in the absence of any other major source of fluoride, such as fluoridated dentifrices and supplements, very little fluorosis (approximately 7–16% mild or very mild) was observed at the time (23,24).

Based on these observations, a daily fluoride intake in excess of 0.10 mg/kg

Send correspondence to Dr. Levy, Department of Preventive and Community Dentistry, College of Dentistry, University of Iowa, Iowa City, IA 52242. E-mail: steven-levy@uiowa.edu. Dr. Guha-Chowdhury was a visiting scholar at the Department of Preventive and Community Dentistry, College of Dentistry, University of Iowa, and is now in private practice in Australia. This paper was supported in part by USPHS grants #R03-DE09200 and R01-DE09551. Paper as presented at the Dietary Fluoride Supplement Workshop, Chicago, IL, January 31–February 1, 1994.

**TABLE 1**
**Fluoride Intake (Means and Ranges) from Diet Alone, Reported from Different Countries**

| Study | Age | Fluoridated Areas | | Nonfluoridated Areas | |
|---|---|---|---|---|---|
| | | mg/Day | mg/kg bw | mg/Day | mg/kg bw |
| ***Dietary survey studies*** | | | | | |
| McClure (USA, 1943) | 1–3 years | 0.42–0.83 | 0.03–0.10 | | |
| | 4–6 years | 0.56–1.11 | 0.02–0.09 | | |
| | 7–9 years | 0.70–1.38 | 0.02–0.07 | | |
| Burt (USA, 1992) | 3–6 months | 0.33* | 0.04–0.07 | | |
| | 6–12 months | 0.43* | 0.04–0.06 | | |
| | 1–3 years | 0.65* | 0.04–0.07 | | |
| | 3–6 years | 0.90* | 0.03–0.05 | | |
| | 6–8 years | 1.00* | 0.03–0.05 | | |
| Ham and Smith (USA, 1974) | 2 years | 0.61 | | | |
| Singer and Ophaug (USA, 1979) | 2 months | 0.63 | 0.13 | 0.05 | 0.01 |
| | 4 months | 0.68 | 0.10 | 0.10 | 0.02 |
| | 6 months | 0.76 | 0.09 | 0.15 | 0.02 |
| Ophaug et al. (USA, 1985) | 6 months | 0.42 | 0.05 | 0.35 | 0.04 |
| | 2 years | 0.62 | 0.05 | 0.21 | 0.03 |
| Featherstone and Shields (USA, 1988) | 6 months | 0.40 | 0.05 | 0.20 | 0.03 |
| Dabeka et al. (Canada, 1982) | 3–6 months | 0.42 | 0.06 | 0.25 | 0.04 |
| | 6–9 months | 0.48 | 0.06 | 0.27 | 0.04 |
| | 9–12 months | 0.56 | 0.05 | 0.28 | 0.03 |
| Hattab and Wei (Hong Kong, 1988) | 6–11 months | 0.23 | 0.03 | | |
| Schamschula et al. (Hungary, 1988) | 4 years | 0.72 | | 0.22 | |
| ***Duplicate-diet studies*** | | | | | |
| Brunetti and Newbrun (USA, 1983) | 3–4 years | 0.33 | | | |
| Chowdhury et al. (New Zealand, 1990) | 11–13 months | | | | |
| Mean | | 0.26 | 0.03 | 0.08 | 0.01 |
| (Range) | | (0.09–0.55) | (0.01–0.06) | (0.04–0.31) | (0.004–0.04) |
| Chowdhury et al. (1993) | 3–4 years | | | | |
| Mean | | 0.36 | 0.019 | 0.15 | 0.01 |
| (Range) | | (0.09–0.74) | (<0.01–0.04) | (0.05–0.31) | (<0.01–0.02) |
| | 7–8 years | | | | |
| Mean | | 0.43 | 0.015 | 0.23 | 0.01 |
| (Range) | | (0.20–0.81) | (0.01–0.03) | (0.09–0.50) | (<0.01–0.02) |

*Uppermost limit of intake.

bw generally is accepted to cause dental fluorosis and intake levels of 0.05–0.07 mg F/kg of body weight frequently are quoted in the literature as being "optimal" for dental health in children aged 1–12 years (19,25,26). However, some investigators consider these "optimal" levels to be threshold levels and have suggested that daily fluoride intake in excess of only 0.05–0.07 instead of 0.10 mg/kg bw could cause dental fluorosis (6).

Burt (27) reviewed the history of the term "optimal" fluoride intake. He traced how McClure's information in 1943 (22) came to be interpreted as a recommendation by several other workers (19,25,26). He pointed out that Farkas and Farkas (25) had quoted a number of personal opinions, many from nonexperts; that Ophaug et al. (26) had cited Farkas and Farkas, and Forester and Schulz (19); and that Forester and Schulz had cited a source to which no reference was given. Based on a report by Ekstrand (28), Burt estimated that the upper limit of fluoride intake for young children should be about 0.05 mg per 100 kcals (418.4 kJ) of energy intake. His estimates matched well with the range of "optimum" fluoride intake in children reported by other investigators (7,22,26,29-33) (Table 1). Burt concluded that, "despite its dubious genesis, empirical evidence suggests that 0.05–0.07 mg F /kg bw per day remains a useful upper (threshold) limit for fluoride intake from all sources in children" (27). Although not specified in his article (27), Burt meant "all sources" to include all dietary and nondietary sources combined (Burt BA. Personal communication, Dec 22, 1993). However, most of the published reports on fluoride intake in children are of dietary fluoride intake only and do not include important potential sources of nondietary fluoride intake in children, especially fluoridated dentifrices and supplements. If these sources were included, then more children would be receiving intake beyond the recommended levels considered to be "optimal" for substantial caries protection and minimal risk of objectionable dental fluorosis.

Burt (27) stated in his review that there is not enough evidence to conclude that fluoride levels in the diet have changed much since the time McClure conducted his study in 1943. However, this conclusion is based on the assumption that McClure's estimation was accurate and that methods used today yield similar results. Such direct comparisons between studies are difficult because methods used in the collection and analysis of diets have varied. Substantial variation exists in the published data for fluoride content of foods, probably because of the use of different analytical techniques and analytical difficulties (34). It is possible that crude distillation methods for the analysis of fluoride used by McClure in 1943 could have led to an overestimation of the fluoride content in foods and that findings from current studies using the more sensitive fluoride electrode probably reflect truer levels of fluoride in food and beverages (35). If so, then it is possible that fluoride in the food chain has increased since water fluoridation was introduced in 1945.

However, relatively more sensitive means of measuring fluoride intake (35,36), such as the duplicate-diet approach to collecting food samples (37-39) and the microdiffusion technique and the fluoride electrode in the isolation and measurement of fluoride (35), appear to indicate a substantially lower level of fluoride intake from food and beverages (including water) in children than has been reported in studies using other methods (Table 1). Brunetti and Newbrun (37) collected duplicates of all food and fluid consumed over 2 to 4 days by 10 healthy, 3- to 4-year-old children in a fluoridated area in the United States. Their average dietary intake was 0.33±0.14 mg F/day. The range and fluoride intake on a body weight basis were not stated. A similar lower level of average dietary intake (0.36 mg/day) was found in children aged 3 to 4 years in a study conducted in New Zealand using a three-day duplicate-diet approach (38). The uppermost limit of fluoride intake from food and beverages (including water) alone in 65 infants aged approximately 12 months was 0.06 mg/kg bw (39); in 34 children aged 3 to 4 years it was 0.04 mg/kg bw; in 34 children aged 7 to 8 years, it was only 0.03 mg/kg bw (38). The duplicate-portion technique provides the most accurate data on the type and quantity of food consumed by an individual (36). However, the logistics of using this approach to determine fluoride intake levels in large-scale studies make it unfeasible.

Most of the other reports on fluoride intake in infants and children in the United States and other parts of the world (Table 1) are based on the analysis of food items in composite food groups, standard food tables, diet records, market-basket collections based on dietary surveys, or hospital diets. All these methods only estimate the quantity of each food consumed using existing survey data, usually only reporting estimated mean intake. Vast differences exist in the amounts of food eaten by subjects of the same age, in food habits, in the type of commercially available foods and beverages, and in the fluoride content of these food items. The duplicate-diet studies suggest that levels of fluoride intake in children from food and beverages (including water) could be much lower than previously reported. These studies and the fact that, on average, water fluoridation could have led to only an increase or to no change in national fluoride intake levels further strengthen the argument that McClure's (22) findings were probably an overestimate.

It is possible that the uppermost limit of fluoride intake (threshold for dental fluorosis) today is still 0.05–0.07 mg / kg bw / day, as suggested by Burt (27). However, today this figure must be clearly stated and recognized to include fluoride intake not only from food and beverages (which is probably less than 0.05–0.07 mg F/kg bw as found in duplicate-diet studies), but also nondietary sources of intake such as dentifrices, dietary fluoride supplements, mouthrinses, and gels. It is important to bear in mind that this threshold level of fluoride intake above which dental fluorosis could occur is still only an estimate and that the threshold level of intake could be even lower than 0.05–0.07 mg/kg bw. In fact some investigators (6,40) suggest that the borderline dose of fluoride intake above which dental fluorosis may develop in the permanent dentition could be as low as 0.03–0.04 mg/kg bw. However, it is not clear whether these lower "thresholds" (6,40) are fluoride intake levels from food and beverages (including water) alone or from all sources.

Clearly, in a biological sense, it is the total ingested and bio-available fluoride that is important in consideration of dental caries prevention and the occurrence of objectionable dental fluorosis. An important issue in the consideration of what constitutes the threshold level of fluoride intake is the differentiation between intake from foods and beverages (including water) only versus total fluoride intake from food and beverages (including water), plus dentifrices, dietary fluoride supplements, rinses, and gels. In addition, more accurate information on background levels of children's fluoride intake from food and beverages (including water) alone is desirable if appropriate dosages for fluoride supplements are to be recommended in the future. Also, if the threshold level is lower than previously believed, then the dosage of dietary fluoride supplements may need to be reduced even further, if they are needed at all.

### Fluoride Intake from Milk and Formula

The fluoride intake of infants from milk, including breastmilk, cow's milk, milk-based commercial formulas, and soy-based formulas, is of interest because it is the main source of nutrition in the first year of life when the permanent anterior teeth are in the developmental stage. The fluoride content of breastmilk is very low and consistently is found to be less than 0.01 ppm (41,42). Cow's milk also contains very low levels of fluoride, generally below 0.05 ppm (42,43). Cow's milk in some modified form (pasteurized, homogenized, evaporated, condensed, dried whole, or dried skim) is the basis for most milk-based formulas, whether ready-to-feed, liquid concentrate, or powder concentrate. The fluoride levels of milk-based formulas available in most countries are reported to be higher than those found in human or cow's milk (44-50). Prior to 1979, the fluoride levels of commercially prepared infant milk- and soy-based formulae available in the United States varied from 0.1 to as high as 0.9 ppm (30,45-48). The variability in the fluoride concentrations of commercially available formulas is related mainly to the water fluoride levels used where the products were manufactured (30,43,49). However, a more recent report indicates that US manufacturers have voluntarily reduced the fluoride content of water used in processing their products resulting in much lower levels (0.05–0.37 ppm) of fluoride in infant formulas (10,49). A report published in 1987 based on data collected in 1982 indicated that fluoride levels of Canadian ready-to-feed formulas contained much higher levels (0.4–2.3 ppm; mean=0.9 ppm) of fluoride (10,43). It has been recommended that infant concentrated formulas should not contain more than 0.4 ppm fluoride (28).

**TABLE 2**
**Distribution of Total Daily Water Fluoride Intake, Standard Weight, and Range of "Optimal" Fluoride Intake by 98 6-month-old Infants (Ref. 56)**

| Percentile | Water Fluoride Intake (mg) | Weight (kg) | "Optimal" Fluoride Intake (mg) |
|---|---|---|---|
| 10 | <0.01 | 6.3 | 0.32–0.44 |
| 25 | 0.01 | 6.9 | 0.35–0.48 |
| 50 | 0.24 | 7.5 | 0.38–0.53 |
| 75 | 0.62 | 8.2 | 0.41–0.57 |
| 90 | 0.93 | 8.7 | 0.44–0.61 |

*Assuming 0.05–0.07 mg F/kg bw.

Some infants react to cow's milk and are fed soy-based formulas. These consistently have been found to contain higher levels of fluoride than milk-based formulas (43,48-52). In a recent study of infant formulas available in Iowa (53), the fluoride level in five ready-to-feed soy-based formulas ranged from 0.17 to 0.38 ppm (mean= 0.27 ppm) and in 16 milk-based formulas ranged from 0.04 to 0.55 ppm (mean=0.17 ppm). Fluoride levels of powder and liquid concentrates of soy- and milk-based formulas when reconstituted with deionized water were similar to the ready-to-feed levels. One formula for infants with sensitivity to intact protein was found to contain a higher level of fluoride (0.55 ppm), probably because of the inclusion of calcium phosphate salts, which often are contaminated with fluoride. When reconstituted with fluoridated tap water, infant formulas (especially those that are milk-based) generally provide substantially higher levels of fluoride than those reconstituted with fluoride-deficient water (43,45-53).

The low levels of fluoride in human and cow's milk as compared with commercial milk- or soy-based formulas available in some countries have a significant impact on the daily fluoride intake of infants and young children. For example, the daily dietary fluoride intake of an infant would be less than 0.01 mg/day if fed only one liter of breastmilk containing <0.01 ppm and intake would be less than 0.05 mg/day if fed only one liter of cow's milk containing <0.05 ppm. However, an infant fed one liter of liquid concentrated infant formula containing 0.3 ppm fluoride and reconstituted with deionized water would receive from 0.15 mg/day, which is substantially more than that received by infants fed exclusively breastmilk or cow's milk. Much higher fluoride (0.65 mg/day) intake occurs when ingesting one liter of concentrated liquid infant formula (0.3 ppm) reconstituted with fluoridated water (1 ppm). Fluoride intake from formula may approximate 1 ppm when receiving one liter of concentrated powder infant formula (0.3 ppm) reconstituted with fluoridated water (1 ppm). Thus, infant formulas reconstituted with higher fluoride water can provide 100 to 200 times more fluoride than breastmilk or cow's milk (28). Also, McKnight-Hanes et al. (50) recently suggested that if infants consuming soy-based formulas only were to receive fluoride supplements, then they could receive greater than currently recommended "optimal" daily dosages of fluoride and be at risk for developing dental fluorosis.

Therefore, if dietary fluoride supplements are to be recommended for very young infants in low fluoride areas, the type of feeding as well as the fluoride content of the water used in reconstituting formulas need to be considered carefully because some infants on infant formulas may require a reduced dosage or no supplementation compared to their counterparts on breastmilk or cow's milk. Because feeding habits change frequently during early infancy, adequate assessment and monitoring of these factors by the prescribing physician or dentists is often very difficult or not practical.

## Fluoride Intake from Water

Approximately 52 percent of the US population receives adjusted fluoridated water and 4 percent receives naturally fluoridated water, which together totaled some 144 million people in 1992 (54). This number represents 62 percent of the US population on public water supplies. The proportion of the population on public water supplies that are fluoridated varies substantially among the states, ranging from 2 percent to 100 percent. Seven states reported fewer than 25 percent of those served by public water systems receiving fluoridated water while 20 states and the District of Columbia reported more than 75 percent served (54). Approximately 23 percent of the population in the West had access to fluoridated public water supplies compared with 78 percent in the Midwest, 63 percent in the South, and 50 percent in the Northeast (55).

The quantities of water ingested by young children show substantial variation. In a recent study (56), data from dietary questionnaires, existing information concerning public water supplies, and fluoride assays of the infants' home and child care drinking water (including tap water, bottled water, and/or filtered water) were used to determine in detail the fluoride intake from water itself and when used to reconstitute infant formulas and other beverages. The estimated total daily water intake for 98 infants aged 6 months varied from 0 to 38 ounces (mean=17 ounces) with approximately 75 percent of this water being derived from water used to reconstitute infant formulas. The estimated fluoride intake from only water mixed with concentrated formula ranged from 0 to 1.12 mg/day (mean=0.28 mg/day). Estimated total fluoride intake from water from all sources (water by itself, and mixed with concentrated formula, beverages, baby foods/cereals, and other foods) ranged from 0 to 1.29 mg/day (mean=0.36 mg/day).

Table 2 relates selected percentiles of the distribution of estimated total water fluoride intake from the Iowa study (56) to the standard distribution of body weights in kilograms of US 6-month-old infants, and the associated "optimal" total fluoride intake of 0.05–0.07 mg/kg bw. At the low end of our distribution of fluoride intake from water, for example the 10th and 25th percentiles up to the median, water fluoride intake was substantially lower than the total daily "optimal" fluoride intake. However, for the upper percentiles, from below the 75th percentile on, the estimated water fluoride intake by itself exceeds the "optimal" total fluoride intake. Specifically, 25 percent of our study sample, or those beyond the 75th percentile, had estimated water fluoride ingestion exceeding 0.62 mg F per day, while only 10 percent of 6-month-old infants, or those beyond the 90th percentile, would be expected to have body weights corresponding to an optimal total fluoride intake beyond 0.61 mg. Individuals with fluoride intake from water exceeding the generally recommended "optimal" total fluoride intake would be at a substantial risk for the occurrence of dental fluorosis, as would others who had lower fluoride intake from water, but also ingested fluoride from dietary fluoride supplements and/or dentifrice. Results concerning 79 infants aged 9 months also showed substantial variation in water intake and estimated fluoride intake from water (57). However, smaller percentages were receiving large quantities of water in reconstituted formula; thus, smaller percentages of the 9-month-old infants were at risk for exceeding the "optimal" fluoride intake from water alone (57).

In determining fluoride intake from tap water, it is important to consider the effect of water filtration systems being used in the home. The majority of home filtration systems are carbon or charcoal filter systems that generally do not remove fluoride. However, the more expensive home distillation and reverse osmosis systems remove the majority of the fluoride. One type of reverse osmosis membrane is capable of removing 90 percent or more of the fluoride, while the second type is able to remove only about 65 percent of the fluoride.

Bottled waters are promoted as a safe source of clean drinking water and sometimes are used instead of tap water for the reconstitution of infant formulas and other beverages. Bottled waters can show considerable variation in fluoride content. Although most bottled waters contain less than 0.3 ppm fluoride, several, especially artesian waters and certain imported mineral waters, contain approximately 1.0 ppm fluoride or more (10,53,58). For example, fluoride assay of 55 bottled waters available in Iowa in 1992–93 showed that 86 percent of them contained <0.3 ppm, 5 percent contained 0.3–0.7 ppm, 4 percent contained 0.71–1.00 ppm, and 5 percent contained >1.0 ppm fluoride (53). In the United States, bottled waters must be tested for fluoride content only once per year (10). The Food and Drug Administration also allows them to contain up to 4.0 ppm fluoride under the Safe Drinking Water Act, but does not require their fluoride levels to be listed (10,59). The bottling of water by one company for sale by another company under another brand name further "confuses the tracking of bottled water fluoride levels" (10).

## Fluoride Intake from Beverages

Studies among children in some countries such as the United States, Canada, and Hong Kong report a substantial increase in the consumption of beverages and a reduction in average tap water consumption (60-62). Specifically, soft drink consumption in the United States has more than doubled over the last 25 to 30 years, with a decline of similar magnitude in average water consumption (10,60). In a report (63) on water consumption in the United States, the sources and mean percentages of total water intake (including water itself, water added to, and water present naturally in different products) in non-breast-fed infants under 1 year of age were 33 percent for baby formula; 25 percent for milk and milk beverages; 16 percent for tap water; 15 percent for baby foods; and 12 percent for other beverages, foods, and juices. In children aged 1 to 10 years the sources and percentages of total water intake were 42 percent from "other" beverages (including carbonated), juices, and foods; 30 percent from tap water; 25 percent from milk and milk beverages; and 3 percent from tea and coffee (63). These results illustrate the relatively small intake of tap water by itself and its prominence in other beverages among infants and young children.

Because the main component of most beverages is water, the fluoride content of these products closely parallels the fluoride content of water used in their processing (30,48,60,61). Fruit juices processed in plants supplied with fluoridated water have been found to contain more fluoride than those processed in plants supplied with nonfluoridated water (30,48). In a study in North Carolina, the fluoride content of 280 available beverage products was found to be highly variable, ranging from <0.1 to as much as 6.7 ppm (64). Many carbonated beverages had fluoride levels close to 1 ppm, juices ranged up to 1.70 ppm (mean=0.36 ppm), and punches up to 1.44 ppm (mean=.33 ppm) (10,64). Using three-day liquid intake diaries and beverage fluoride microdiffusion assay results, Pang et al. (64) estimated the mean daily fluoride intakes from beverages, excluding water and milk, to be 0.36 mg for 2–3-year-old children, 0.54 mg for 4–6-year-old children, and 0.60 mg for 7–10-year-old children. However, because concentrated beverages were reconstituted with deionized water and water itself was excluded, it is possible that these values underestimated the fluoride intake of some children (10). In analyses of ready-to-feed juices and juice drinks available in Iowa, fluoride levels ranged from 0.03 to 2.80 ppm (mean=0.56 ppm) (65). Grape juices had the highest fluoride levels ranging from 0.05 to 2.80 ppm (mean=1.08 ppm). In another report (66) as much as 6.8 ppm fluoride was found in grape juice. The authors reported that the high fluoride content of grape juices was believed to be the result of the use of fluoride-containing insecticide spray (66).

Not only can the fluoride concentrations vary among products, but fluoride levels in the same product can vary also depending on the fluoride level of the water used in its processing. Limited information is available from the manufacturers concerning the consistency of and actual fluoride levels of their products. For these reasons, and with the apparent continued expansion of the availability of different beverages, the tracking of fluoride content of beverages and the assessment of fluoride intake from these sources can be very complex. For example, all of one company's infant juices distributed to Iowa were reportedly manufactured with fluoridated water and we found that 94 percent had fluoride levels above 0.70 ppm (65). In contrast, the other company's products were produced at three different sites, two nonfluoridated and one fluoridated, and the same product (brand, flavor) had different levels of fluoride depending on the site of manufacture, with neither site nor fluoride level listed on the product (65). In some cases we have been able to successfully link product code information with information from the manufacturer such as production sites or water fluoride levels; however, this linkage involves very detailed inquiries of manufacturers and of parents about their children's intake.

Added to this problem of variable fluoride levels is the fact that beverages prepared with fluoridated water often are distributed and consumed in communities without controlled water fluoridation, contributing to "diffusion" of fluoride's benefits (67), also sometimes called the halo effect. For example, Clovis and Hargreaves (61) reported substantial variation in their estimates of fluoride intake from fluids alone among 400 12-year-old Canadian children. Their findings ranged from 0.40 to 2.45 mg in fluoridated (mean=1.08 ppm) areas and from 0.02 to 0.82 mg in nonfluoridated (mean=0.23 ppm) areas. Both groups received soft drinks and juices manufactured in fluoridated Edmonton and the main source of fluoride in the nonfluoridated community was carbonated beverages prepared with fluoridated water. Although "fluoridated" products are reported to have been distributed to "nonfluoridated" areas, it can also work in reverse. Recent inquiry has established that a major brand of soft drink distributed to Minnesota and Iowa was manufactured with water from a deep well containing low fluoride (0.1 ppm), although the production site is located near a large fluoridated metropolitan area that had been assumed to be the water source. Another variation of this diffusion effect is when children attending child care facilities in a fluoridated area receive water with a higher level of fluoride than that in their area of residence (10). The relative magnitude of this diffusion effect throughout the United States requires further study.

Another important source of fluoride ingestion is tea (31,68-70). Raw tea leaves can contain as much as 400 ppm fluoride (68). When infused with deionized water, the fluoride content of tea has been found to range from 0.1 to 4.2 ppm fluoride, with an average of about 3 ppm (68-70). A cup of tea (200 mL) daily, therefore, could yield on average about 0.6 mg F/day. Where tea drinking is common, it can be an important source of fluoride intake. For example, average daily fluoride intake from tea among "high tea consumers" was reported by Hargreaves (70) to be about 1 mg. He reported that 18 percent of nonnative Canadian children and 85 percent of native Indian children drank tea routinely (10,70). In the United Kingdom nearly 70 percent of children younger than 7 years of age and some infants as young as 12 months of age were found to be drinking tea (68).

Besides tea leaves, infant cereals, infant chicken products, fish products, and some sea foods contain high levels of fluoride. Infant chicken products have been found to contain about 0.6 to 10.6 ppm fluoride (30,45) and tinned fish up to 40 ppm fluoride (71). Dried sea foods, which constitute a significant part of the diet in some cultures, also contain high levels of fluoride (about 3–290 ppm) (71). The high levels of fluoride in these products are a result of the inclusion of bone and shell, which accumulate fluoride (72).

Therefore, just because a child resides in a fluoridated or nonfluoridated area is not a sufficient indicator of that child's ingestion of fluoride from water. Today's decisions about the need for dietary fluoride supplementation and any specific recommendations about dosage must consider identification of all main sources of fluid intake and the specific effects of a possible diffusion effect.

## Fluoride Intake from Dentifrices

Nearly 90 percent or more of all dentifrices sold in the United States, Canada, and other western countries contain fluoride, commonly in the form of either sodium monofluorophosphate or sodium fluoride (73). The fluoride concentration in dentifrices in the United States ranges from 1,000 to 1,500 ppm (10,73,89). Fluoride dentifrices are used almost universally and are an important source of fluoride intake because fluoride ingestion from toothpaste is common in children (10,89). Data from the National Health Interview Survey (NHIS) series show that 33 percent of children under age 2 years and 91 percent of those aged 2 to 4 years were using fluoride dentifrices (55). Many studies report that the amount ingested, which can range from essentially none to 100 percent (10,74-89), is inversely related to age and directly related to the amount applied to the toothbrush. In one study of 2–3-year-old children (84), the age during which there is an increased risk of developing dental fluorosis of the maxillary incisors (90-92), subjects used an average of approximately 0.25 to 0.30 g of dentifrice per brushing and ingested up to 50 percent or more of it (10,89). This level of toothpaste ingestion is expected to provide an average of approximately 0.15 mg of fluoride per brushing when using a fluoridated (1,000 ppm) dentifrice. Therefore, ingestion of toothpaste can contribute substantial amounts of fluoride and it has been concluded that some young children may be ingesting enough fluoride from dentifrice to cause dental fluorosis (10,89,93,94). In one study the use of "children's flavored" dentifrices resulted in the use of larger quantities of dentifrice (95), whereas another unpublished study found no differences in the amount of children's flavored and standard flavored dentifrice used by children (96).

Table 3 provides detailed summary data on fluoride intake from dentifrices among young children (10,89). These estimates of fluoride intake are for each brushing, and because many children brush more than once daily, the actual amount of fluoride intake in some children could be higher than shown in the table (10,89). Dentifrice use and ingestion clearly are quite variable (75-89). About 20 percent of children have intake levels well beyond the mean results most often quoted in the literature (10,89). "Thus, the use of only mean figures can be misleading and both the mean and the distribution should be considered in policy-making efforts. Virtually all authors have noted that some children could ingest more fluoride from dentifrice alone than is recommended as a

**TABLE 3**
**Dentifrice Use and Ingestion (Refs. 10, 89)**

| | | | Dentifrice per Brushing (g) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Used | | | Ingested | | | |
| Study (Ref.) | Age (Yrs) | Number | Mean | Range | 90% | Mean | Range | 90% | Mean % Ingested |
| Ericsson* (74) | 4 | 10 | 0.45 | — | — | 0.13 | 0.04–0.30 | — | 30 |
| | 6 | 10 | 0.45 | — | — | 0.12 | 0.06–0.19 | — | 26 |
| Hargreaves (75) | 3–6 | 44 | 1.38 | 0.34–2.94 | 2.04 | 0.38 | 0–1.16 | 0.80 | 28 |
| Barnhart (76) | 2–4 | 62 | 0.86 | 0.19–2.41 | — | 0.30 | — | 0.73 | 35 |
| | 5–7 | 56 | 0.94 | 0.15–2.08 | — | 0.13 | — | 0.27 | 14 |
| | 11–13 | 73 | 1.10 | 0.31–2.00 | — | 0.07 | — | 0.12 | 6 |
| | 20–25 | 60 | 1.39 | 0.42–3.29 | — | 0.04 | — | 0.12 | 3 |
| Glass (77) | 8–10 | 67 | 1.04 | 0.23–2.57 | 1.57 | 0.12 | 0–0.41 | 0.23 | 12 |
| Baxter (79) | 5–16 | 85 | — | — | — | 0.19 | up to 0.75 | 0.47 | — |
| | 5–6 only | 8 | — | — | — | 0.27 | — | — | — |
| Dowell (80) | 3 | 115 | 0.55 | 0.07–1.97 | — | — | — | — | — |
| Bruun† (82) | 3 | 63 | 1.1 | 0.17–3.0 | 1.6§ | — | — | — | — |
| | 7 | 31 | 1.5 | 0.20–3.7 | 2.3§ | — | — | — | — |
| | 9 | 27 | 2.3 | 1.20–4.3 | 3.1§ | — | — | — | — |
| | 9‡ | 24 | 1.6 | 0.54–2.5 | 1.8§ | — | — | — | — |
| | 16 | 9 | 3.4 | 2.10–4.9 | 4.3§ | — | — | — | — |
| | 16‡ | 25 | 2.1 | 0.72–4.9 | 2.7§ | — | — | — | — |
| Salama (83) | 3–10 | 19 | 1.0¶ | 1.0–1.0¶ | 1.0¶ | 0.36 | 0.08–0.82 | — | 36 |
| Simard (84) | 2–3 | 5 | 0.46 | — | — | 0.28 | — | — | 59 |
| | 4 | 9 | 0.78 | — | — | 0.39 | — | — | 48 |
| | 5 | 9 | 0.65 | — | — | 0.22 | — | — | 34 |
| Naccache (85) | 3 | 23 | 0.50 | — | — | 0.18 | — | — | 41 |
| | 5 | 25 | 0.47 | — | — | 0.11 | — | — | 30 |
| Simard (86) | 1 | 15 | 0.16 | 0.03–0.51 | 0.40 | — | — | — | — |
| Naccahe (87) | 2 | 36 | 0.62 | — | — | 0.33 | — | — | 65 |
| | 4 | 81 | 0.45 | — | — | 0.22 | — | — | 49 |
| | 7 | 77 | 0.50 | — | — | 0.16 | — | — | 34 |
| Maurice (88) | 1–4 | 59 | 0.43• | 0.01–2.39 | 0.89 | — | — | — | — |
| | | | 0.47∞ | 0.03–1.27 | 0.92 | — | — | — | — |

*Average of results obtained with two different dentifrices.
†Results from two-week usage and dietary period.
‡Dentifrice tube orifice was 21% smaller than for other subgroups.
¶All subjects used 1.0 g.
§For this study these are 75th percentiles, not 90th.
•Single observation.
∞Weekly use and diary period.
Note: The quantity of fluoride in mg can be calculated from the quantitiy of dentifrice in g as follows: if 1,000 ppm fluoride, then number of mg fluoride=number of g of dentifrice; if 1,100 ppm fluoride, then number of mg fluoride=1.1 times the number of g of dentifrice; and if 1,500 pm fluoride, then number of mg fluoride=1.5 times the number of g of dentifrice.

total daily fluoride ingestion. When combined with fluoride from other regular sources such as beverages, 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 (10,89, 94). The use and ingestion of dentifrices, therefore, can contribute significantly to the total daily fluoride intake in children and in some studies has been associated with dental fluorosis (10,89,97-99). To reduce the risk of fluorosis, it has been suggested that use of higher concentration fluoride dentifrices by preschool children be avoided, that only small quantities of paste be used under parental direction and supervision, that further development and testing of lower concentration fluoride dentifrices be encouraged, and that dentifrice tubes dispense smaller quantities (10,13,15,27, 89,93,94,100,101) "so that inappropriate eating of fluoride dentifrice is avoided" (10,89).

In making recommendations for the use of and appropriate dosages of dietary fluoride supplements in children, therefore, it is very important to determine background levels of fluoride intake not only from food and beverages (including water), but also from dentifrice ingestion.

## Fluoride Intake from Mouthrinses

The use and ingestion of fluoride mouthrinses is a potential source of fluoride intake in children. Fluoride mouthrinses available for weekly use (daily if at high risk for caries) contain 0.20 percent NaF (about 910 ppm fluoride) and the ones for daily use contain 0.05 percent NaF (about 230 ppm fluoride). National Health Interview Survey (NHIS) data in 1989 (55) showed that 1 percent of those under 2 years of age and 9 percent of those 2 to 4 years of age used fluoride mouthrinses. A reported increase in use of mouthrinses from 1983 to 1989 by preschool children occurred primarily among black children, children living in poverty, and those whose head of household had no college education. Nationally, about 25 percent of school-aged children reportedly used fluoride mouthrinses at home and 14 percent did so at school. Black children of school age also were more likely to use mouthrinses than preschool children of this race (55).

The amount of rinse ingested following the use of mouthrinses is variable and has been reported to be inversely related to age and experience with rinsing, and directly related to rinsing time and volume of rinse used (9,74,93,102). In one study (74), following rinsing with 7 mL of 0.05 percent NaF mouthrinse, 3-year-old children swallowed an average of 26 percent of the mouthrinse (0.44 mg F), 4-year-old children 24 percent (0.42 mg F), and 5- and 6-year-old children 22 percent (0.35 mg F). Another study (102) found that, after excluding the few children who swallowed the whole rinse, the mean quantity of fluoride ingested by 98 inexperienced and 376 experienced preschool children aged 3 to 5 years was 0.40 mg F for a 0.05 percent NaF rinse and 1.60 mg for a 0.2 percent NaF rinse. These amounts were approximately 25 to 35 percent of the total rinse. Mean ingestion figures mask the importance of ingestion of all the mouthrinse by some children and are, therefore, underestimates of their importance on an individual basis. Even if 5 mL of a 0.2 percent sodium fluoride solution were to be used by young children instead of 10 mL as recommended for older children and adults, a maximum of 4.6 mg of fluoride could be ingested. If only 40 percent were to be swallowed, the child would receive 1.8 mg of fluoride and if 20 percent were to be swallowed, 0.9 mg of fluoride could be ingested from this source alone. Fluoride mouthrinses are, therefore, generally not recommended for use by children younger than school age because of their inability to avoid swallowing much of it (9).

Although fluoride mouthrinses are not used routinely by young children and are in fact intended to be used only with caution prior to school age, the use of fluoride mouthrinses by children in the United States is widespread (103,104), as seen in the NHIS data (55). If even a small percentage of those US children rinsing are in preschool, Head Start, or kindergarten rinse programs, it means that a large number of children are probably ingesting a substantial dose of fluoride (1.0 to 1.5 mg) on at least 20 to 30 occasions throughout the year.

## Fluoride Intake from Professional and Self-applied Fluoride Gels

The amount of fluoride ingested following professional topical application of a fluoride gel (typically containing 12,300 ppm fluoride for APF) is variable, but generally ranges from 10 to 35 mg of fluoride when not using suction and from 2 to 7 mg fluoride when using suction with subsequent expectoration (105-108). Clearly, these large quantities of ingested fluoride would exceed "optimal" fluoride intake. But because these applications are relatively infrequent, generally at 3- to 12-month intervals, exposure to these high levels is not a regular occurrence and it is unclear whether they influence fluorosis risk. However, appropriate precautions should be taken to minimize gel ingestion and they should be recommended only for caries-active children or those with increased caries risk (15,93).

Fluoride gels also are available for self-use. The estimated amount of fluoride ingested when 5 drops of 0.5 percent fluoride gel (1.25 mg F) were applied on a toothbrush and teeth brushed for one minute among a small number of children aged 7 to 13 years varied from 0.37 to 1.22 mg (mean=0.78 mg), or 30 percent to 98 percent (mean=67%) of the amount used (109). For preschool children, who probably would ingest even more fluoride, these gels potentially constitute a substantial additional source of ingested fluoride that should be considered when making patient recommendations, if any, for dietary fluoride supplementation.

## Dietary Fluoride Supplements

Dietary fluoride supplements in the form of tablets, drops, lozenges, and rinses are recommended for use by children in low fluoride areas so that they receive amounts of fluoride similar to those received by their counterparts resident in fluoridated areas. Because of problems with compliance, however, few children receive them on a continuous basis (10). For those children who do take fluoride supplements regularly, they constitute a substantial source of daily fluoride intake (10).

National Health Interview Survey data from 1989 (55) show that about 15 percent of those under 2 years of age, 16 percent of those aged 2–4 years, and 8 percent of those aged 5–17 years used dietary fluoride supplements. In the NIDR national children's survey, 54 percent of those aged 5–17 years reported some lifetime use of supplements (110). In each age group, the use of supplements was greatest among whites, children not living in poverty, children whose heads of household had some college education, and those living in the west and northeast regions of the country (55).

Early estimates of fluoride intake of children from food and beverages (including water) provided by McClure in 1943 (22) served as a basis for calculating dosages of fluoride supplements for children residing in low-fluoride areas. However, use of supplements with 0.5 to 1.0 mg F/day, using McClure's findings as a guide, by very young children in nonfluoridated areas was associated with some dental fluorosis in 67 percent of children taking these supplements (111). As discussed before, it is possible that McClure had overestimated the true levels of fluoride intake from food and beverages (including water) and as a result the fluoride supplement dosages recommended for use in low fluoride areas were too high. The observed high prevalence of dental fluorosis led to a reduction in the fluoride dosage from 0.5 mg/day to 0.25 mg/day for children younger than 2 years of age (20,21). Although it is now known that excessive intake of fluoride even after 2 years of age can cause dental fluorosis in the permanent anterior teeth, the recommended dosage for children 2 years of age and older has remained at 0.5 to 1.0 mg/day.

Young children who ingest higher dosages of supplements than are indicated or ingest them while receiving optimally fluoridated water are at increased risks of fluorosis (112). Although the majority of US physicians and dentists prescribe supplements for some of their patients, relatively few assay their patients" water supplies for fluoride (10). Some states have no organized programs for providing water fluoride assay services, further compromising the provision of appropriate fluoride supplement prescriptions (113). In one study, approximately one-third of child patients received an "incorrect" fluoride supplement even after the provider and/or the parent had the water tested for fluoride (114). Also, those most likely to receive supplements on a regular basis are those of higher socioeconomic status who also are most likely to be receiving other fluoride exposures and therefore are at increased fluorosis risk (10).

Use of fluoride supplements has been identified as the major risk factor for dental fluorosis in a number of recent studies (98,115,116). One of the possible reasons for this occurrence is that estimated levels of fluoride intake from food and beverages (including water) by children might be higher that their actual intake, resulting in much higher dosages of fluoride from dietary fluoride supplements for children living in low fluoride areas than fluoride intake from other sources by children living in fluoridated areas. In addition, determinations of fluoride supplement dosage recommendations did not include possible fluoride ingestion from dentifrices. Also, the amounts of fluoride derived from food and beverages in nonfluoridated areas have not been subtracted from those received in fluoridated areas. Other possible reasons for the frequent identification of dietary fluoride supplements as a risk factor for dental fluorosis are the lack of appropriate water fluoride assays resulting in the prescription of inappropriate dosages of supplements by physicians and dentists, and the low statistical power of most studies to assess other potential risk factors, such as fluoride dentifrices (89,117,118). Because supplement use is a risk factor for dental fluorosis, currently recommended levels of fluoride supplementation, especially in children older than 2 years of age, need to be reassessed. The recommended dosage schedule was recently reduced in Canada, with emphasis placed on the conservative use of dietary fluoride supplements by limiting them to children at high risk of caries (15).

Although dietary fluoride supplements in low-fluoride areas are meant to provide amounts of fluoride equal to those ingested in fluoridated areas, the form of delivery is quite different from that of fluoride derived from food and beverages (including water) where consumption is spread over a whole day. The possible effects on human teeth of divided (as provided from food and beverages) or single (as provided by supplements) doses of fluoride are not well understood. In experiments with rats, enamel fluorosis developed with single-peak plasma fluoride levels of 0.2 ppm or more and in the presence of even lower levels (<0.1 ppm) with weeklong plasma fluoride levels (119, 120). With the knowledge that the continuous presence of low levels of fluoride in the oral environment posteruptively is more beneficial to caries prevention than single systemic doses, many have called for reconsideration of the rationale for the use of dietary fluoride supplements or for them to be used only for children at high risk of dental caries (10,15,27,114,121).

If fluoride supplements are to be used, then accurate information on not only fluoride content of the residential water source, but on background levels of fluoride intake from food and beverages, type of feeding, kind of water used in reconstituting foods and beverages, use of beverages versus water at home or at child care, the possibility of a diffusion effect, and the use and ingestion of dentifrice and even mouthrinses and gels may need to be considered in making recommendations for appropriate dosages of fluoride supplements in children. These complex sets of data are difficult to obtain even on a research basis, much less in daily dental and medical practice.

## Estimated Total Fluoride Intake

Although a determination of the distribution of fluoride intake from all sources is difficult using existing data (10), Pendrys and Stamm (115) presented estimates for 2-year-olds from the three most important sources—namely, diet, dietary fluoride supplements, and dentifrice. Their estimated means (and ranges) of daily fluoride intakes in a fluoridated (1 ppm) area were: 0.6 mg (range=0.5–0.6) from diet (including water and beverages), 0 mg from dietary fluoride supplements, 0.3 mg (range=0–2.0 mg) from dentifrice, with a total mean intake of 0.9 mg (range=0.5–2.6). For a nonfluoridated area (0 ppm) they estimated that diet contributed 0.3 mg (range=0.2–0.3), dietary fluoride supplements 0.5 mg, and dentifrices 0.3 mg (range=0.2–2.0 mg), with a total intake of 1.1 mg (range=0.7–2.8 mg). Their data probably present too narrow a range of fluoride intake from the diet and intake from fluoride supplements probably are underestimated because many children receive "inappropriately high supplement dosages or receive supplements when none are indicated" (10). The wide ranges of estimated intake from dentifrice reviewed earlier are reflected in their estimates.

Table 4 shows a number of different hypothetical conservative combinations of possible daily fluoride intake from the three main sources for those aged 6, 12, 24, and 36 months, with associated mean intake per kg bw. For simplicity, extreme dietary and dentifrice intake patterns have been excluded. These data emphasize the importance of considering all sources of fluoride intake when formulating policies on the use of dietary fluoride supplements. Many rows of the table show levels of fluoride intakes that appear to be low or moderate values when considering individual sources, but result in substantial or "excessive" fluoride intake when combined. For example, a 10 kg infant aged 12 months receiving 0.5 mg from diet, 0.5 mg from dentifrice, and 0.25 mg from supplement, which are within the "optimal" levels of intake separately, could receive a total of 1.25 mg F/day or 0.125 mg F/kg bw from the three sources combined and thereby clearly exceed the recommended "optimal" level of 0.05–0.07 mg/kg bw. Similarly, a 12 kg infant aged 24 months receiving 0.5 mg from diet, 0.5 mg

**TABLE 4**
**Hypothetical Examples of Daily Fluoride Intake by Preschool Children from Three Main Sources (Diet, Dentifrice, and Dietary Fluoride Supplement)**

| Fluoride Intake (mg/Day) from | | | | Total Fluoride Intake (mg/kg bw) by Age (Months) | | | |
|---|---|---|---|---|---|---|---|
| Diet | Dentifrice | Supplement | Total | 6 mos (8 kg*) | 12 mos (10 kg) | 24 mos (12 kg) | 36 mos (14 kg) |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0.25 | 0.25 | 0.031 | 0.025 | 0.021 | 0.018 |
| 0 | 0 | 0.50 | 0.50 | 0.063 | 0.050 | 0.042 | 0.036 |
| 0 | 0 | 1.00 | 1.00 | 0.125 | 0.100 | 0.083 | 0.071 |
| 0 | 0.25 | 0 | 0.25 | 0.031 | 0.025 | 0.021 | 0.018 |
| 0 | 0.25 | 0.25 | 0.50 | 0.063 | 0.050 | 0.042 | 0.036 |
| 0 | 0.25 | 0.50 | 0.75 | 0.094 | 0.075 | 0.063 | 0.054 |
| 0 | 0.25 | 1.00 | 1.25 | 0.156 | 0.125 | 0.104 | 0.089 |
| 0 | 0.50 | 0 | 0.50 | 0.063 | 0.050 | 0.042 | 0.036 |
| 0 | 0.50 | 0.25 | 0.75 | 0.094 | 0.075 | 0.063 | 0.054 |
| 0 | 0.50 | 0.50 | 1.00 | 0.125 | 0.100 | 0.083 | 0.071 |
| 0 | 0.50 | 1.00 | 1.50 | 0.189 | 0.150 | 0.125 | 0.107 |
| 0 | 1.00 | 0 | 1.00 | 0.125 | 0.100 | 0.083 | 0.071 |
| 0 | 1.00 | 0.25 | 1.25 | 0.156 | 0.125 | 0.104 | 0.089 |
| 0 | 1.00 | 0.50 | 1.50 | 0.189 | 0.150 | 0.125 | 0.107 |
| 0 | 1.00 | 1.00 | 2.00 | 0.250 | 0.200 | 0.167 | 0.143 |
| 0.50 | 0 | 0 | 0.50 | 0.063 | 0.050 | 0.042 | 0.036 |
| 0.50 | 0 | 0.25 | 0.75 | 0.094 | 0.075 | 0.063 | 0.054 |
| 0.50 | 0 | 0.50 | 1.00 | 0.125 | 0.100 | 0.083 | 0.071 |
| 0.50 | 0 | 1.00 | 1.50 | 0.189 | 0.150 | 0.125 | 0.107 |
| 0.50 | 0.25 | 0 | 0.75 | 0.063 | 0.050 | 0.042 | 0.036 |
| 0.50 | 0.25 | 0.25 | 1.00 | 0.125 | 0.100 | 0.083 | 0.071 |
| 0.50 | 0.25 | 0.50 | 1.25 | 0.156 | 0.125 | 0.104 | 0.089 |
| 0.50 | 0.25 | 1.00 | 1.75 | 0.219 | 0.175 | 0.146 | 0.125 |
| 0.50 | 0.50 | 0 | 1.00 | 0.125 | 0.100 | 0.083 | 0.071 |
| 0.50 | 0.50 | 0.25 | 1.25 | 0.156 | 0.125 | 0.104 | 0.089 |
| 0.50 | 0.50 | 0.50 | 1.50 | 0.189 | 0.150 | 0.125 | 0.107 |
| 0.50 | 0.50 | 1.00 | 2.00 | 0.250 | 0.200 | 0.167 | 0.143 |
| 0.50 | 1.00 | 0 | 1.50 | 0.189 | 0.150 | 0.125 | 0.107 |
| 0.50 | 1.00 | 0.25 | 1.75 | 0.219 | 0.175 | 0.146 | 0.125 |
| 0.50 | 1.00 | 0.50 | 2.00 | 0.250 | 0.200 | 0.167 | 0.143 |
| 0.50 | 1.00 | 1.00 | 2.50 | 0.313 | 0.250 | 0.208 | 0.179 |
| 1.00 | 0 | 0 | 1.00 | 0.125 | 0.100 | 0.083 | 0.071 |
| 1.00 | 0 | 0.25 | 1.25 | 0.156 | 0.125 | 0.104 | 0.089 |
| 1.00 | 0 | 0.50 | 1.50 | 0.189 | 0.150 | 0.125 | 0.107 |
| 1.00 | 0 | 1.00 | 2.00 | 0.250 | 0.200 | 0.167 | 0.143 |
| 1.00 | 0.25 | 0 | 1.25 | 0.156 | 0.125 | 0.104 | 0.089 |
| 1.00 | 0.25 | 0.25 | 1.50 | 0.189 | 0.150 | 0.125 | 0.107 |
| 1.00 | 0.25 | 0.50 | 1.75 | 0.219 | 0.175 | 0.146 | 0.125 |
| 1.00 | 0.25 | 1.00 | 2.25 | 0.281 | 0.225 | 0.189 | 0.161 |
| 1.00 | 0.50 | 0 | 1.50 | 0.189 | 0.150 | 0.125 | 0.107 |
| 1.00 | 0.50 | 0.25 | 1.75 | 0.219 | 0.175 | 0.146 | 0.125 |
| 1.00 | 0.50 | 0.50 | 2.00 | 0.250 | 0.200 | 0.167 | 0.143 |
| 1.00 | 0.50 | 1.00 | 2.50 | 0.313 | 0.250 | 0.208 | 0.179 |
| 1.00 | 1.00 | 0 | 2.00 | 0.250 | 0.200 | 0.167 | 0.143 |
| 1.00 | 1.00 | 0.25 | 2.25 | 0.281 | 0.225 | 0.189 | 0.161 |
| 1.00 | 1.00 | 0.50 | 2.50 | 0.313 | 0.250 | 0.208 | 0.179 |
| 1.00 | 1.00 | 1.00 | 3.00 | 0.375 | 0.300 | 0.250 | 0.214 |

*Mean body weights.

from dentifrice, and 0.50 mg from supplement would receive a total of 1.5 mg F/day or 0.125 mg F/kg bw. An average weight 36-month-old child receiving 0.5 mg from diet, 1.0 mg from dentifrice, and 1.0 mg from supplement would receive a total of 2.5 mg F/day or 0.179 mg F/kg bw. In addition, extreme dietary intake patterns, increased brushing frequency, or increased ingestion of fluoride dentifrice, mouthrinse, gel, or supplement could increase substantially the total ingestion (10,115). Many intake combinations toward the estimated top end of the range of total intake in Table 4 certainly exceed the optimal. And one must keep in mind that intake is spread over a wide range of body weights and an exact threshold dose has not been established (10).

## Conclusions

The majority of studies, despite their many methodological and other differences, have consistently found that the level of fluoride intake is quite variable among individuals. A substantial percentage of individuals ingest levels well beyond that of the mean for that source (10). Also, in most reports, a smaller proportion of children, often 10 percent to 20 percent of the study population, received several times as much exposure as the mean (10). Because of this finding, most authors commented that some children in their studies probably ingested sufficient quantities of fluoride from only the single source or category being studied to exceed the "optimal" fluoride intake and be at increased risks of dental fluorosis (10). Although most of the results are presented as mean ingestion values, this substantial variation above and below the mean must be considered carefully when studying the complexity of fluoride ingestion (10,89).

By extrapolation, if approximately 10 percent to 20 percent of individuals receive "excess" systemic fluoride intake from a single source alone, then the likelihood of "excess" fluoride intake from all sources would be at least 30 percent to 40 percent or more (10). In fact several reports of prevalence rates for mostly mild fluorosis are in the 20 percent to 80 percent range (10,99,104,101,116,122-125).

Because detailed data are not available from comprehensive, individual studies concerning the distribution of total fluoride intake from multiple sources, determination with any precision of the relative proportional contribution from each of these sources on a population basis is very difficult. However, a reasonable conclusion is that most preschool children, whether living in fluoridated or nonfluoridated regions, are regularly ingesting nontrivial quantities of fluoride from dentifrice, from beverages and from foods. When these quantities are added together, they may be sufficient to place a substantial proportion of children into a category of increased fluorosis risk, even though few studies of fluorosis have been designed to investigate these relationships in sufficient detail or had adequate statistical power for documentation. Dietary fluoride supplement use is less widespread, but is a substantial source of ingestion among those using them and their use has been shown to be associated with increased fluorosis risk.

When considering fluoride recommendations on a group basis, all major sources of fluoride ingestion, such as diet, dentifrice, and fluoride supplements, must be considered so that total daily intake of fluoride can be estimated (10). To this end, efforts should be renewed to determine and regularly monitor the fluoride levels of beverages and foods and have their fluoride levels made available to the profession and the public. If necessary, fluoride levels of infant formulas and other products should be modified (10). In addition, attempts must be made to avoid excessive ingestion of fluoride dentifrice and further investigate the cariostatic effect of lower fluoride concentration dentifrices. Finally, dietary fluoride supplements should be used conservatively, with appropriate prior consideration of such fluoride exposures as intake from multiple water sources, other beverage sources, and dentifrice ingestion patterns (10). Determination of dietary (food and beverage) exposures are very complex and least controllable (10). Therefore, major consideration should be given to adjustment of the recommended dietary fluoride supplement dosage schedule and efforts to limit the excessive ingestion of dentifrice by young children while at risk of dental fluorosis (10). Such efforts will help to ensure that fluoride provides maximum caries protection while minimizing the risk of objectionable dental fluorosis (10).

## References


1. Silverstone LM. Remineralization phenomena. Caries Res 1977;11:59-84.
2. Arends J, ten Cate JM. Tooth enamel remineralization. J Cryst Growth 1981;53: 135-47.
3. Featherstone JDB, Glena R, Shariati M, Shields CP. Dependence of in vitro demineralization of apatite and remineralization of dental enamel on fluoride concentrations. J Dent Res 1990;69:620-5.
4. Fejerskov O, Thylstrup A, Larsen MJ. Clinical and structural features and possible pathogenic mechanisms of dental fluorosis. Scan J Dent Res 1977;85:510-34.
5. Richards A, Kragstrup J, Josephsen J, Fejerskov O. Dental fluorosis developed in post-secretory enamel. J Dent Res 1986; 65:1406-9.
6. Fejerskov O, Stephen KW, Richards A, Speirs R. Combined effect of systemic and topical fluoride treatments on human deciduous teeth-case studies. Caries Res 1987;21:452-9.
7. Schamschula RG, Un PSH, Sugar E, et al. Daily fluoride intake from the diet of Hungarian children in fluoride deficient and naturally fluoridated areas. Acta Physiolog Hung 1988;72:229-35.
8. Oliveby A, Lagerlof F, Ekstrand J, Dawes C. Studies on fluoride excretion in human whole saliva and its relation to flow rate and plasma fluoride levels. Caries Res 1989;23:243-6.
9. Whitford GM, Allmann DW, Shahed AR. Topical fluorides: effects on physiologic and biochemical processes. J Dent Res 1987;66:1072-8.
10. Levy SM. Review of fluoride exposures and ingestion. Community Dent Oral Epidemiol 1994;22:148-52.
11. International Association of Dental Research. International symposium on fluorides: mechanisms of action and recommendations for use. J Dent Res 1990; 69:505-831.
12. American Association of Public Health Dentistry. Symposium on appropriate uses of fluoride—considerations for the '90s. J Public Health Dent 1991;51:20-63.
13. Bawden JW, ed. Proceedings of the workshop: changing patterns in systemic fluoride intake. J Dent Res 1992;71:1212-65.
14. Efficacy of caries preventive strategies. Proceedings of the Scientific Conference of the European Academy of Paediatric Dentistry. Caries Res 1993;27:2-43.
15. Clark C, ed. Report of the working group of the Canadian workshop on the evaluation of current recommendations concerning fluorides. Community Dent Oral Epidemiol 1994;22:140-3.
16. National Health and Medical Research Council. The effectiveness of water fluoridation. Canberra: Australian Government Publishing Service, 1991.
17. Young FE. Report of the Ad Hoc Subcommittee on Fluoride. Review of fluoride benefits and risks. Washington, DC: US Department of Health and Human Services, Public Health Service, Feb 1991.
18. Subcommittee on Health Effects of Ingested Fluoride, Committee on Toxicology, Board on Environmental Studies

and Toxicology, Commission on Life Sciences, National Research Council. Health effects of ingested fluoride. Washington, DC: Academy Press, 1993.
19. Forrester DJ, Schulz EM Jr, eds. International Workshop on Fluorides and Dental Caries Reductions. Baltimore, MD: University of Maryland, 1974.
20. American Academy of Pediatrics, Council on Nutrition. Fluoride supplementation—revised dosage schedule. Pediatr 1979;63:150-2.
21. American Academy of Pediatrics, Committee on Nutrition. Fluoride supplementation. Pediatr 1986;77:758-61.
22. McClure FJ. Ingestion of fluoride and dental caries, quantitative relations based on food and water requirements of children 1 to 12 years old. Am J Dis Child 1943;66:362-9.
23. Dean HT. The investigation of physiological effects by the epidemiological method. In: Moulton FR, ed. Fluorine and dental health. Washington, DC: American Association for the Advancement of Science, 1943:23-31.
24 Russell AL. Dental fluorosis in Grand Rapids during the seventeenth year of fluoridation. J Am Dent Assoc 1962; 65:608-12.
25. Farkas CS, Farkas EJ. Potential effect of food processing on the fluoride content of infant foods. Sci Total Environ 1974;2: 399-405.
26. Ophaug RH, Singer L, Harland BF. Dietary fluoride intake of 6- month and 2-year-old children in four dietary regions of the United States. Am J Clin Nutr 1985; 42:701-7.
27. Burt BA. The changing patterns of systemic fluoride intake. J Dent Res 1992;71: 1228-37.
28. Ekstrand J. Fluoride intake in early infancy. J Nutr 1989;119:1856-60.
29. Ham MP, Smith MD. Fluoride studies related to the human diet. Can J Res 1950; 28:227-33.
30. Singer L, Ophaug R. Total fluoride intake of infants. Pediatr 1979;63:460-6.
31. Featherstone JDB, Shields CP. A study of fluoride intake in New York State residents. Final report. Albany, NY: New York State Health Department, 1988.
32. Dabeka RW, McKenzie AD, Conacher HG, Kirkpatrick DC. Determination of fluoride in Canadian infant foods and calculation of fluoride intakes by infants. Can J Public Health 1982;73:188-91.
33. Hattab FN, Wei SHY. Dietary sources of fluoride for infants and children in Hong Kong. Pediatr Dent 1988;10:13-18.
34. Rao GS. Dietary intake and bioavailability of fluoride. Ann Rev Nutr 1984;4:115-36.
35. Venkateswarlu P. Overview of analytical methods for fluorine in air, water, soil, vegetation, body fluids, and tissues. In: Shupe JL, Peterson HB, Leone NC, eds. Fluorides: effects on vegetation, animals, and humans. Washington, DC: Paragon Press, 1984:21-52.
36. Birkhed D. Behavioral aspects of dietary habits and dental caries. Diet, nutrition and dental caries. Caries Res 1990;24:27-35.
37. Brunetti A, Newbrun E. Fluoride balance of children 3 and 4 years old [Abstract]. Caries Res 1983;17:171.
38. Chowdhury NG, Drummond BK, Smillie AC. Fluoride intake in children and caries activity [Abstract]. J Dent Res 1993; 72:230.
39. Chowdhury NG, Brown RH, Shepherd MG. Fluoride intake of infants in New Zealand. J Dent Res 1990;69:1828-33.
40. Baelum V, Fejerskov O, Manji F, Larsen MJ. Daily dose of fluoride and dental fluorosis. Tandlaegebladet 1987;91:452-6.
41. Ekstrand J, Spak CJ, Falch J, Afseth J, Ulvestad H. Distribution of fluoride to human breastmilk following intake of high doses of fluoride. Caries Res 1984; 18:93-5.
42. Backer-Dirks O, Jongeling-Eijndhoven J, Flissebaalje T, Gedalia I. Total and free ionic fluoride in human and cow's milk as determined by gas-liquid chromatography and the fluoride electrode. Caries Res 1974;8:181-6.
43. Dabeka RW, McKenzie D. Lead, cadmium, and fluoride levels in market milk and infant formulas in Canada. J Ofl Anal Chem Assoc 1987;70:754-7.
44. Ericsson Y, Ribellius U. Wide variations of fluoride supply to infants and their effect. Caries Res 1971;5:78-88.
45. Wiatrowski E, Kramer L, Osis D, Spencer H. Dietary fluoride intake of infants. Pediatr 1975;55:517-22.
46. Stamm JW, Kuo HC. Fluoride concentrations in prepared infant foods [Abstract]. J Dent Res 1977;56:628.
47. Tinanoff N, Mueller B. Fluoride content in milk and formula for infants. J Dent Child 1978;45:53-5.
48. Adair SM, Wei SH. Supplemental fluoride recommendations for infants based on dietary fluoride intake. Caries Res 1978;12:76-82.
49. Johnson J Jr, Bawden JW. The fluoride content of infant formulas available in 1985. Pediatr Dent 1987;9:33-7.
50. McKnight-Hanes MC, Leverett DH, Adair SM, Shields CP. Fluoride content of infant formulas: soy-based formulas as a potential factor in dental fluorosis. Pediatr Dent 1988;10:189-94.
51. Levy SM, Zarei-MZ. Evaluation of fluoride exposures in children. J Dent Child 1991;59:467-73.
52. Levy SM, Maurice TJ, Jakobsen JR. Feeding patterns, water sources, and fluoride exposures of infants and 1-year-olds. J Am Dent Assoc 1993;124:65-9.
53. Van Winkle S, Levy SM, Kiritsy MC, Heilman JR, Wefel JS, Marshall T. Water and formula fluoride concentrations: significance for infants fed formula. Pediatr Dent 1995;17:305-10.
54. US Department of Health and Human Services. Fluoridation Census, 1992. Atlanta, GA: Public Health Service, Centers for Disease Control and Prevention, Sept 1993.
55. Wagener DK, Nourjah P, Horowitz AM. Trends in childhood use of dental care products containing fluoride: United States, 1983-1989. Advance data from Vital and Health Statistics. Hyattsville, MD: National Center for Health Statistics #219; Nov 20, 1992.
56. Levy SM, Kohout FJ, Guha-Chowdhury N, Kiritsy MC, Heilman JR, Wefel JS. Infants' fluoride intake from drinking water alone, and from water added to formula, beverages and food. J Dent Res 1995;74:1399-407.
57. Levy, SM, Kohout FJ, Kiritsy MC, Helman JR, Wefel JS. infants' fluoride ingestion from water, supplements and dentifrice. J Am Dent Assoc 1995;126:1625-32.
58. Flaitz CM, Hill NC, Hicks MJ. A survey of bottled water usage by pediatric dental patients: implications for dental health. Quintessence Int 1989;20:847-52.
59. Committee on Safe Drinking Water, National Research Council. Drinking water and health. Vol. 6. National Academy Press, 1986:266-71.
60. Ismail AI, Burt BA, Eklund SA. The cariogenicity of soft drinks in the United States. J Am Dent Assoc 1984;109:241-5.
61. Clovis J, Hargreaves JA. Fluoride intake from beverage consumption. Community Dent Oral Epidemiol 1988;16:11-15.
62. Chao ESM, Anderson GH, Thompson GW, Hargreaves JA, Peterson RD. A longitudinal study of dietary changes of a sample of Ontario children. II: Food intake. J Can Diet Assoc 1984;45:112-18.
63. Ershow AG, Cantor KP. Total water and tap water intake in the United States: Population-based estimates of quantities and sources. National Cancer Institute, 1989; #263-MD-810264.
64. Pang PTY, Phillips CL, Bawden JW. Fluoride intake from beverage consumption in a sample of North Carolina children. J Dent Res 1992;71:1382-8.
65. Kiritsy MC, Levy SM, Warren JJ, Guha-Chowdhury N, Heilman JR, Marshall T. Assessing fluoride concentrations of juices and juice-flavored drinks. J Am Dental Assoc 1996;127:895-902.
66. Stannard JG, Shim YS, Kritsineli M, Labropoulou P, Tsamtsouris A. Fluoride levels and fluoride contamination of fruit juices. J Clin Pediatr Dent 1991;16:38-40.
67. Ripa LW. A half-century of community water fluoridation in the United States: review and commentary. J Public Health Dent 1993;53:17-44.
68. Duckworth SC, Duckworth R. The ingestion of fluoride in tea. Br Dent J 1978;145: 368-70.
79. Hargreaves JA, Stahl MJ. Fluoride content of teas [Abstract]. J Dent Res 1986;65: B176.
70. Hargreaves JA. Fluoride in teas and tea drinking by Canadian children [Abstract]. J Dent Res 1978;57:299.
71. Wei SHY, Hattab FN. Fluoride content of dried sea foods [Abstract]. J Dent Res 1987;66:957.
72. Dolan T, Legette L, McNeal J, Malonoski AJ. Determination of fluoride in deboned meat. J Assoc Off Anal Chem 1978;61: 982-5.
73. Newbrun E. Topical fluoride therapy: discussion of some aspects of toxicology, safety, and efficacy. J Dent Res 1987;66: 1084-6.
74 Ericsson Y, Forsman B. Fluoride retained from mouthrinsing and dentifrices in preschool children. Caries Res 1969;3: 290-9.
75. Hargreaves JA, Ingram GS, Wagg BJ. A gravimetric study of the ingestion of toothpaste by children. Caries Res 1972; 6:236-43.
76. Barnhart WE, Hiller LK, Leonard GJ,

Michaels E. Dentifrice usage and ingestion among four age groups. J Dent Res 1974;53:1317-22.
77. Glass RL, Peterson JK, Zuckerberg DA, Naylor MN. Fluoride ingestion resulting from the use of a monofluorophosphate dentifrice by children. Br Dent J 1975;138: 423-6.
78. Ekstrand J, Ehrnebo M. Absorption of fluoride from fluoride dentifrices. Caries Res 1980;14:96-102.
79. Baxter PM. Toothpaste ingestion during toothbrushing by schoolchildren. Br Dent J 1980;148:125-8.
80. Dowell TB. The use of toothpaste in infancy. Br Dent J 1981;150:247-9.
81. Ekstrand J, Koch G, Petersson LG. Plasma fluoride concentrations in preschool children after ingestion of fluoride tablets and toothpaste. Caries Res 1983;17:379-84.
82. Bruun C, Thylstrup A. Dentifrice usage among Danish children. J Dent Res 1988; 67:1114-17.
83. Salama F, Whitford GM, Barenie JT. Fluoride retention by children from toothbrushing [Abstract]. J Dent Res 1989;68: 335.
84. Simard PL, Lachapelle D, Trahan L, Naccache H, Demers M, Brodeur JM. The ingestion of fluoride dentifrice by young children. J Dent Child 1989;56:177-81.
85. Naccache H, Simard PL, Trahan L, Demers M, Lapointe C, Brodeur JM. Variability in the Ingestion of toothpaste by preschool children. Caries Res 1990;24: 359-63.
86. Simard PL, Naccache H, Lachapelle D, Brodeur JM. Ingestion of fluoride from dentifrices by children aged 12 to 24 months. Clin Pediatr 1991;30:614-17.
87. Naccache H, Simard PL, Trahan L, et al. Factors affecting the ingestion of fluoride dentifrice by children. J Public Health Dent 1992;52:222-6.
88. Maurice TJ, Levy SM, Jakobsen JR. Dentifrice use among preschool children. J Am Dent Assoc 1993;124:57-60.
89. Levy SM. A review of fluoride intake from fluoride dentifrice. J Dent Child 1993;60:115-24.
90. Evans RW. Changes in dental fluorosis following an adjustment to the fluoride concentration of Hong Kong's water supplies. Adv Dent Res 1989;3:154-60.
91. Evans RW, Stamm JW. Dental fluorosis following downward adjustment to fluoride in drinking water. J Public Health Dent 1991;51:91-8.
92. Evans RW, Stamm JW. An epidemiologic estimate of the critical period during which human maxillary central incisors are most susceptible to fluorosis. J Public Health Dent 1991;51:251-9.
93. Ripa LW. A critique of topical fluoride methods (dentifrices, mouthrinses, operator and self-applied gels) in an era of decreased caries and increased fluorosis prevalence. J Public Health Dent 1991; 51:23-41.
94. Beltran ED, Szpunar SM. Fluoride in toothpastes for children: suggestions for change. Pediatr Dent 1988;3:185-8.
95. Levy SM, Maurice TJ, Jakobsen JR. A pilot study of preschoolers' use of regular flavored dentifrices and those flavored for children. Pediatr Dent 1992;14: 388-91.
96. Cheng MC, Taulbee JD, Flennoy NJ. A comparison of ingestion of children's flavored and standard flavored dentifrices by children in two age groups. Cincinnati, OH: Procter & Gamble Company, Sharon Woods Technical Center, 1993 (unpublished report).
97. Osuji OO, Leake JL, Chipman ML, Nikiforuk G, Locker D, Levine N. Risk factors for dental fluorosis in a fluoridated community J Dent Res 1988;67:1488-92.
98. Pendrys DG, Katz RV. Risk of enamel fluorosis associated with fluoride supplementation, infant formula, and fluoride dentifrice use. Am J Epidemiol 1989; 130:1199-208.
99. Lalumandier JA, Rozier RG. The prevalence and risk factors of fluorosis among children in a pediatric dental practice. Pediatr Dent 1995;17:19-25.
100. Winter GB, Holt RD, Williams F. Clinical trial of a low-fluoride toothpaste for young children. Int Dent J 1989;39:227-35.
101. Horowitz HS. The need for toothpastes with lower than conventional fluoride concentration for preschool-aged children. J Public Health Dent 1992;52:216-21.
102. Wei SHY, Kannelis MJ. Fluoride retention after sodium fluoride mouthrinsing by preschool children. J Am Dent Assoc 1983;106:626-9.
103. Miller AJ, Brunelle JA. A summary of the NIDR community caries prevention demonstration program. J Am Dent Assoc 1983;107:265-9.
104. Szpunar SM, Burt BA. Dental caries, fluorosis, and fluoride exposure in Michigan Schoolchildren. J Dent Res 1988;67:802-6.
105. Ekstrand J, Koch G. Systemic fluoride absorption following fluoride gel application [Abstract]. J Dent Res 1980; 59:1067.
106. LeCompte EJ, Doyle TE. Oral fluoride retention following various topical application techniques in children. J Dent Res 1982;61:1397-400.
107. LeCompte EJ, Whitford GM. Pharmacokinetics of fluoride from APF gel and fluoride tablets in children. J Dent Res 1982; 61:469-72.
108. Tyler JE, Andlaw RJ. Oral retention of fluoride after application of acidulated phosphate fluoride gel in air-cushion trays. Br Dent J 1987;162:422-5.
109. Bell RA, Whitford GM, Barenie JT, Myers DR. Fluoride retention in children using self-applied topical fluoride products. Clin Prev Dent 1985;7:22-7.
110. Brunelle JA, Carlos JP. Recent trends in dental caries in US children and the effect of water fluoridation. J Dent Res 1990;69: 23-7.
111. Aasenden R, Peebles TC. Effects of fluoride supplementation from birth on human deciduous and permanent teeth. Arch Oral Biol 1974;19:321-4.
112. Pendrys DG, Morse DE. Use of fluoride supplementation by children living in fluoridated communities. J Dent Child 1990;57:343-7.
113. Levy SM, Shavlik DA. The status of water fluoride assay programs and implications for prescribing of dietary fluoride supplements. J Dent Child 1991;58:23-6.
114 Levy SM, Muchow G. Provider compliance with recommended dietary fluoride supplement protocol. Am J Public Health 1992;82:281-3.
115. Pendrys DG, Stamm JW. Relationship of total fluoride intake to beneficial effects and enamel fluorosis. J Dent Res 1990;69: 529-38.
116. Ismail AI, Brodeur JM, Kavanagh M, Boisclair G, Tessier C, Picotte L. Prevalence of dental caries and dental fluorosis in students, 11-17 years of age, in fluoridated and nonfluoridated cities in Quebec. Caries Res 1990;24:290-7.
117. Rozier RG. Reaction paper: appropriate uses of fluoride-consideration for the '90s. J Public Health Dent 1991;51:56-9.
118. Pendrys DG. Reaction paper: some perspectives on the appropriate uses of fluoride for the '90s and beyond. J Public Health Dent 1991;51:56-9.
119. Angmar-Mansson B, Ericsson Y, Ekberg O. Plasma fluoride and enamel fluorosis. Calcif Tissue Res 1976;22:77-84.
120. Angmar-Mansson B, Whitford GM. Enamel fluorosis related to plasma fluoride levels in the rat. Caries Res 1984;18: 25-32.
121. Szpunar SM, Burt A. Fluoride supplements: evaluation of appropriate use in the United States. Community Dent Oral Epidemiol 1992;20:148-54.
122. Williams JE, Zwemer JD. Community water fluoride levels, preschool dietary patterns, and the occurrence of fluoride enamel opacities. J Public Health Dent 1990;50:276-81.
123. Woolfolk NW, Faja BW, Bagramian RA. Relation of sources of systemic fluoride to prevalence of dental fluorosis. J Public Health Dent 1989;49:78-82.
124. Skotowski MC, Hunt RJ, Levy SM. Risks factors for dental fluorosis in pediatric dental patients. J Public Health Dent 1995;55:154-9.
125. Clark DC. Changing trends in the prevalence of dental fluorosis in North America: a review of the literature. Community Dent Oral Epidemiol 1994;22:148-52.