

# Position of the Academy of Nutrition and Dietetics: The Impact of Fluoride on Health

## ABSTRACT

It is the position of the Academy of Nutrition and Dietetics to support optimal systemic and topical fluoride as an important public health measure to promote oral health and overall health throughout life. Fluoride is an important element in the mineralization of bone and teeth. The proper use of topical and systemic fluoride has resulted in major reductions in dental caries and its associated disability. Dental caries remains the most prevalent chronic disease in children and affects all age groups of the population. The Centers for Disease Control and Prevention has named fluoridation of water as one of the 10 most important public health measures of the 21st century. Currently, >72% of the US population that is served by community water systems benefits from water fluoridation. However, only 27 states provide fluoridated water to more than three quarters of the state's residents on public water systems. Fluoride also plays a role in bone health. However, at this time, use of high doses of fluoride for osteoporosis prevention is considered experimental only. Dietetics practitioners should routinely monitor and promote the use of fluorides for all age groups.

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## POSITION STATEMENT

It is the position of the Academy of Nutrition and Dietetics to support optimal systemic and topical fluoride as an important public health measure to promote oral health and overall health throughout life.

**F**LUORIDE IS A NATURAL element that is considered a beneficial nutrient at optimal levels<sup>1</sup> and is important to the integrity of bone and teeth. About 99% of the fluoride in the body is in the hard tissues.<sup>2</sup> When consumed in optimal amounts in water and food and used topically in fluoridated dentifrices, oral rinses, gels, foams, and professionally applied office treatments, fluoride increases tooth mineralization, helps reduce dental enamel demineralization and promote dental enamel remineralization, and helps reduce dentin hypersensitivity.

The use of fluorides for the prevention of dental caries is recognized as the most effective dental public health measure in existence.<sup>3,4</sup> Fluoride is beneficial to all age groups throughout the life cycle. Recent statistics show that adults are just as likely to experience new dental caries as children.<sup>5,6</sup> Fluoride is important for bone health as well, through its role in mineralization. The Dietary Reference Intakes establish recommendations for fluoride intake<sup>1</sup> (see the Table for these recommendations). Dietetics practitioners should

promote optimum fluoride use as they would other nutrients essential for health.

## PHYSIOLOGY OF FLUORIDE IN THE BODY

Typically, about 80% of dietary calcium is absorbed. Body tissue and fluid concentrations are directly related to intake and are not homeostatically regulated. About 99% of body fluoride is in calcified tissues in both rapidly and slowly exchangeable pools. Fluoride elimination is almost totally via the kidneys through unrestricted filtration through the glomeruli. The degree of tubular resorption is inversely related to tubular fluid pH. Fluoride balance at any age is dependent on absorption and excretion. About half of absorbed fluoride is retained by uptake into calcified tissues and half excreted in the urine in healthy young or middle-aged adults. As much as 80% can be retained by young children as a result of increased uptake by the developing bone and teeth. In older individuals, it is likely that more is excreted than retained. Fluoride balance is determined by the blood-bone-fluoride steady state. Fluoride balance is generally positive, but if chronic intake is not sufficient to main-

tain or increase plasma concentrations, negative fluoride balance can occur due to mobilization from calcified tissues.<sup>1</sup>

## Role of Fluoride in Bone Health

Research has shown that in large enough doses, fluoride can stimulate bone cell (osteoblast) proliferation and increase new mineral deposition in cancellous bone. These effects are mediated by fluoride ions' incorporation into bone crystals, which increases the size and, thus, decreases the solubility of the bone (apatite) crystals. Larger crystals are more resistant to osteoclastic attack (osteoclasts are cells involved in bone resorption). However, the amount of fluoride in the water supply considered optimal to promote oral health (1 ppm or 1 mg/L), is not considered sufficient to stimulate osteoblast activity or prevent osteoporotic fractures.<sup>7</sup> Studies suggest concentrations of sodium fluoride in the water supply would need to reach a threshold of 4 ppm to promote osteoblast activity.<sup>8</sup> Meta-analysis of the efficacy of fluoride therapy (at fluoride levels much higher than from water fluoridation) on bone loss and fractures<sup>9</sup> and other comprehensive reviews<sup>10,11</sup> have determined that although fluoride has an ability to

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This Academy position paper includes the authors' independent review of the literature in addition to a systematic review conducted using the Academy's Evidence Analysis Process and information from the Academy's Evidence Analysis Library. Topics from the Evidence Analysis Library are clearly delineated. The use of an evidence-based approach provides important added benefits to earlier review methods. The major advantage of the approach is the more rigorous standardization of review criteria, which minimizes the likelihood of reviewer bias and increases the ease with which disparate articles can be compared. For a detailed description of the methods used in the evidence analysis process, access the Academy's Evidence Analysis Process at [www.andevidencelibrary.com/eaprocess](http://www.andevidencelibrary.com/eaprocess).

Conclusion Statements are assigned a grade by an expert work group based on the systematic analysis and evaluation of the supporting research evidence. Grade I=Good; Grade II=Fair; Grade III=Limited; Grade IV=Expert Opinion Only; and Grade V=Not Assignable (because there is no evidence to support or refute the conclusion). See grade definitions at [www.andevidencelibrary.com](http://www.andevidencelibrary.com).

Evidence-based information for this and other topics can be found at [www.andevidencelibrary.com](http://www.andevidencelibrary.com).

increase bone mineral density in the lumbar spine, it does not cause a reduction in vertebral fractures<sup>12</sup> and can increase side effects. Evidence from randomized clinical trials is insufficient to support a cause-and-effect relationship between the amount of fluoride in drinking water and bone health status.<sup>13,14</sup> This position is supported by osteoporosis clinical practice guidelines from Canada<sup>15</sup> and the United States.<sup>16</sup>

**Role of Fluoride in Dental Health**

The primary role of fluoride is in the prevention of tooth decay (dental caries). Dental caries is a transmissible, multifactorial disease that is the most common chronic condition of childhood (five times more common than childhood asthma and seven times more common than hay fever<sup>3</sup>).

Dental caries results when acidogenic bacteria colonized on tooth surfaces metabolize fermentable carbohydrates to acids (eg, acetic, butyric, formic, lactic, and propionic acid), which demineralize tooth enamel. From 1999 through 2004, 42% of children aged 2 to 11 years had dental car-

**Table.** Dietary Reference Intakes for fluoride<sup>a</sup>

Age group	Dietary Reference Intakes for Fluoride		
	Reference weights g (lb)	Adequate intake (mg/day)	Tolerable upper limit (mg/day)
Infants 0-6 mo	7 (16)	0.01	0.7
Infants 6-12 mo	9 (20)	0.5	0.9
Children 1-3 y	13 (29)	0.7	1.3
Children 4-8 y	22 (48)	1.0	2.0
Children 9-13 y	40 (88)	2.0	10
Boys 14-18 y	64 (142)	3.0	10
Girls 14-18 y	57 (125)	3.0	10
Males 19 y and older	76 (166)	4.0	10
Females 19 y and older	61 (133)	3.0	10

<sup>a</sup>The Dietary Reference Intakes (DRI) are guidelines set by the Institute of Medicine of the US National Academy of Sciences detailing the known nutrient requirements for human males and females by age group. The DRI system is used by both the United States and Canada and is the basis for the information on Nutrition Facts labels. The strength of the science determines which of the following guidelines are set for a specific nutrient: Recommended Dietary Allowances (RDA), the daily dietary intake level of a nutrient considered sufficient by the Food and Nutrition Board to meet the requirements of nearly all (97% to 98%) healthy individuals in each life-stage and sex group; Adequate Intake, where no RDA has been established, but the amount established is somewhat less firmly believed to be adequate for everyone in the demographic group; Estimated Average Requirements, expected to satisfy the needs of 50% of the people in that age group based on a review of the scientific literature; and, Tolerable Upper Intake Levels, to caution against excessive intake of nutrients that can be harmful in large amounts. This is the highest level of daily consumption that current data have shown to cause no side effects in humans when used indefinitely.

ies in their primary teeth, and 59% of adolescents aged 12 to 19 years had dental caries in their permanent teeth.<sup>17</sup> In addition, 91% of US adults and 93% of Americans aged 60 years and older have experienced tooth decay.<sup>18</sup> Furthermore, great disparity exists in the distribution of dental caries in the United States, with the poor suffering a disproportionately high share of the disease burden.<sup>19</sup> Dental caries can have serious health effects throughout life, including contributing to failure to thrive in children, causing the oral pain that can interfere with desire and ability to eat, and contributing to substantial loss of school and work days.<sup>20</sup>

The relationship between fluoride and dental caries was first noted in the early part of the 20th century, when it was observed that residents living in areas of the country with naturally high levels of fluoride in the water had teeth that were highly resistant to caries, although they were brown-stained.<sup>21</sup> It was later determined that fluoride at lower "optimal" concentrations of 0.7 to 1.2 ppm in the water supply imparted protection against development of dental caries and reduced the overall risk of developing fluorosis (tooth defects caused by excessive fluoride dur-

ing tooth development) (see later section Dental Fluorosis and Bone Health).

The later part of the 20th century saw a major decline in the prevalence and severity of dental caries in many developed nations, attributed in large part to community water fluoridation and other fluoride sources.<sup>22,23</sup> Still the worst affected are the underserved of all age groups who do not have access to dental care and preventive services such as fluoride.

As a result, in 2000 the Surgeon General proclaimed a crisis in oral health in the United States and convened a conference to address the issues.

**Mechanisms of Fluoride Action on Teeth**

Fluoride functions to enhance tooth mineralization and remineralization, decrease and reverse tooth demineralization, and inhibit the metabolism of the acid-producing bacteria responsible for dental caries.<sup>24</sup>

Fluoride incorporated into the developing enamel of teeth pre-eruptively results in a crystalline tooth structure that has increased resistance to caries. However, recent research has found that the primary action of fluoride oc-

curs topically after tooth eruption with consistent application, and the benefits continue throughout life.<sup>22,24</sup> The maximum caries-prevention benefit is achieved when both systemic and topical sources of fluoride are utilized.<sup>25</sup>

### Systemic Effects of Fluoride on Teeth (Pre- and Post-Eruptive)

Fluoride is found in small amounts in most soil, water, plants, and animals and, as such, is a normal component of all diets. Once absorbed into the bloodstream, fluoride is either deposited into bones and developing teeth or excreted in the urine. Pre-eruptively, during tooth development, fluoride is incorporated into the developing tooth's mineralizing structure and helps increase resistance to acid demineralization. After tooth eruption, ingested fluoride is secreted in the saliva and contributes topically to tooth protection. Systemic fluoride benefits developing teeth from before birth until all teeth have erupted (typically through age 12 years). The protective effects via saliva are lifelong. Saliva contains water, protein, calcium, phosphates, fluoride, bicarbonates, and immunoglobulins. Consequently, saliva is important for enamel remineralization, acid dilution and neutralization, and oral clearance of food debris. However, pre-eruptive fluoride is no longer considered the major mechanism by which fluoride provides optimum protection against dental caries.<sup>25,26</sup>

### Topical Effects of Fluoride on Teeth (Post-Eruptive)

Topical mechanisms are now considered the primary means by which fluoride imparts protection to teeth, and the topical benefits of fluoride are now considered independent of the systemic effects for preventing dental caries. The post-eruptive beneficial effect of fluoride likely occurs primarily from the presence of fluoride in the fluid phase at the tooth enamel surface. The frequency of fluoride exposure to the tooth surface is of prime importance for maintaining high fluoride concentration in the fluid phase of enamel surfaces, which will prevent caries and enhance the remineralization of early carious lesions.<sup>26</sup> In addition to its direct mineralizing effect on enamel, fluoride also affects oral plaque bacteria.

These bacteria secrete acids onto tooth surfaces (the byproducts of carbohydrate fermentation), which initiate tooth demineralization. The entry of fluoride into the bacterial cell interferes with acid production, thus reducing potential enamel destruction. People of all ages benefit from the topical effects of fluoride, whether or not they had pre-eruptive systemic fluoride as children.<sup>27,28</sup>

### SOURCES, INDICATIONS, AND EFFICACY OF FLUORIDE

Fluoride can be obtained from fluoridated drinking water; foods and beverages made with fluoridated water; other beverage sources, such as tea; and from oral health products, such as fluoride oral rinses, fluoride-containing dentifrices, topically applied gels and foams, and dietary fluoride supplements.<sup>29</sup>

#### Determining Fluoride Intake

Because of the wide availability of fluoride sources, the varied fluoride levels in foods and beverages, the effects of home water treatments and filtration systems, and the variability of fluoride in bottled waters, total fluoride intake is difficult to determine.<sup>30,31</sup> In addition, the diffusion of fluoride into non-fluoridated areas from bottled beverages, processed foods, and other sources, can blur the effect of the water supply alone.<sup>32</sup>

#### Fluoridated Water

Water and water-based beverages are the chief sources of dietary fluoride. It is estimated that, on average, about 80% of dietary fluoride comes from tap and bottled water and water-based beverages, such as teas, coffee, carbonated beverages, beers, and ready-to-drink juices and drinks.<sup>33</sup> The estimated amount of fluoride consumed from fluoridated drinking water alone by adults ranges from 1.8 to 2.7 mg per day. The average child under age 6 years consumes <0.5 L water/day and would consume <0.5 mg/day fluoride from optimally fluoridated drinking water. In recent years, there has been a trend toward consumption of less tap water in the home and greater consumption of drinks processed elsewhere, including bottled waters.<sup>34</sup> The fluoride content of community water supplies is

available through the local department of public health. The fluoride content of individual well water can vary considerably in fluoride content and should be tested by local or state public health departments or private laboratories for fluoride content. Home water purification and filter systems can also affect the fluoride content of the water. The fluoride in commercial bottled waters is also variable and might be listed on the package label.

**Fluoridation of Community Water Supplies.** Fluoridation of public water supplies continues to be the most cost-effective dental public health measure in existence.<sup>35</sup> The latter part of the 20th century saw a major decline in the prevalence and severity of dental caries in many developed nations, attributed in large part to community water fluoridation (beginning in the 1940s) and other fluoride sources.<sup>36</sup> Community water fluoridation is, by definition, the adjustment of fluoride in a water supply to a proposed optimal concentration of 0.7 ppm. This recommended level of fluoride is considered optimal for caries prevention and safety.<sup>1</sup> Studies continue to show that water fluoridation reduces enamel caries in children by  $\geq 20\%$  and helps prevent root surface caries and tooth loss in adults as well. Water fluoridation is particularly beneficial for individuals living in communities with fewer resources, who have a high burden of dental caries and less access to oral health care and alternative fluoride resources.<sup>37</sup> *Healthy People 2020* objectives for the nation set a target goal of 79.6% of the population using piped water to have that water optimally fluoridated.<sup>38</sup> By 2008, 72.4% of the US population served by public water supplies had access to fluoridated water.<sup>39</sup> The *Healthy People 2010* target of 75% had been met by 27 states and the District of Columbia.<sup>39</sup> However, only 27 states provide fluoridated water to more than three quarters of the state's residents on public water systems.<sup>40</sup>

**Cost and Cost Savings of Community Water Fluoridation.** Water fluoridation continues to be the most cost-effective community-based approach to dental caries prevention in the United States in terms of cost per saved tooth surface, and has the benefit of

reaching all segments of a population, regardless of socioeconomic status or age. In most communities, every \$1 invested in fluoridation saves \$38 or more in treatment costs.<sup>41</sup> In 2004, an estimated \$78 billion was spent on dental services. This represented about 5% of all expenditures for personal health care in the United States. The national average cost to fill one cavity with dental amalgam is approximately \$65—the approximate cost of providing fluoridation to an individual for a lifetime.<sup>42</sup>

**Antifluoridation Movements and Sentiment.** Although the proportion of the US population having access to fluoridated community water supplies continues to rise,<sup>42</sup> decisions to fluoridate community water supplies are made at the local level through public referenda, and can change with election cycles. This public decision process is used, often effectively, by those opposing water fluoridation.

The charges raised by opponents tend to be more sophisticated variations on themes used since the inception of water fluoridation, namely, unproven adverse health consequences (eg, cancer, acquired immunodeficiency syndrome [AIDS]) and infringement on freedom of choice. Their strong appeals and messages associating fluoridation with cancer and AIDS, although disproven, can and have had a powerful influence on the public.<sup>43-45</sup> Although antifluoridationists have gained much publicity in an attempt to create the illusion of scientific controversy over fluoridation, claims of health hazards from water fluoridation at the appropriate level are unfounded. Fluoridation is perhaps the most thoroughly studied community health measure in recent history.

Today, the challenges to increasing and maintaining community water fluoridation are many and include:

- lack of awareness of the importance of fluoridation and lack of recognition of the current oral problems of society by those who vote on fluoridation legislation (eg, scientists, policymakers, and the public);
- misperception that fluoridation is no longer needed or effective;

- difficulty navigating the political processes needed for the adoption of water fluoridation;
- unsubstantiated claims or fear tactics made by fluoridation opponents that influence public opinion against fluoridation; and
- an unsupportive political environment from a fiscal standpoint. Because many of the public water systems that are not fluoridated serve small populations, this increases the per capita cost of fluoridation.<sup>41</sup>

### Fluoride in Foods and Beverages

In addition to drinking fluoridated water, foods and beverages prepared with fluoridated water are also sources of fluoride.<sup>46</sup> In general, however, the fluoride content of branded, purchased foods tends to be low. Some bottled waters contain fluoride, but most do not. The US Food and Drug Administration does not require bottlers to list the fluoride content of bottled water, but does require fluoride additives to be listed. In 2006, the US Food and Drug Administration approved the labeling statement “drinking fluoridated water may reduce the risk of tooth decay” if the bottled water contains >0.6 mg/L up to 1 mg/L.<sup>31</sup> The National Fluoride database from the US Department of Agriculture Nutrient Data Laboratory provides a nationally representative database of the fluoride concentration in food and beverages consumed in the United States.<sup>33</sup>

**Fluoride and Infant Formulas.** For infants from birth to age 12 months of age who consume reconstituted infant formula as the main source of nutrition, caregivers should use powdered or liquid concentrate infant formulas reconstituted with optimally fluoridated water (while being cognizant of the potential for increasing children’s risk for fluorosis).<sup>47,48</sup> For caregivers who might be concerned about the potential for increasing children’s risk of enamel fluorosis, ready-to-feed formula or powdered or liquid concentrate formulas can be reconstituted with fluoride-free or low-fluoride-containing water. These are waters labeled “purified,” “demineralized,” “deionized,” “distilled,” or “produced through reverse-osmosis.” Caregivers can check with their local department of public health to determine the fluoride content of

their community water supply or they can have well water analyzed for fluoride content.<sup>49,50</sup>

**Fluoride Dietary Supplements.** The prescription of dietary fluoride supplements for children living in nonfluoridated areas has been an alternative to water fluoridation for caries prevention since the 1940s. However, the increased risk to children of developing mild fluorosis (see the following section on fluorosis), often associated with the inappropriate use of dietary supplements during the first 3 years of life,<sup>39,51</sup> has resulted in a change in guidelines for the use of fluoride supplements.

An expert panel of the American Dental Association Council on Scientific Affairs, via an evidence-based analysis process, now recommends that fluoride supplements be prescribed only for children at high risk of developing dental caries and whose primary source of drinking water is deficient in fluoride. The value of fluoride in caries prevention is considered to outweigh concern about enamel fluorosis in children at high risk for developing caries.<sup>25,35,52-56</sup>

Several factors should be assessed before deciding whether or not fluoride supplementation is indicated. First is a determination of the fluoride level of the primary water source. The local health department can provide information on the fluoride content of water from public systems. Private water sources, such as well water, can vary tremendously in fluoride content from location to location and should be tested yearly for fluoride content at the local department of public health laboratory.

Because foods processed or reconstituted with fluoridated water can add considerably to total fluoride consumption (particularly in infants), potential sources of fluoride intake in children’s diets should be identified before any fluoride supplementation is recommended.<sup>52,57</sup>

Children’s risk of caries should also be assessed. Several risk assessment tools are available in the literature.<sup>58,59</sup>

Fluoride supplements can be in drops or tablet form. Tablets should be slowly dissolved to enhance the topical effects of the fluoride. Because fluoride supplements can exert a topical effect on

**Figure.** Clinical recommendations for the use of dietary fluoride supplements. Republished with permission of ADA Publishing Co, Inc, from Rozier and colleagues<sup>57</sup>; permission conveyed through Copyright Clearance Center, Inc.

enamel when distributed to the oral cavity via saliva, the recommendation for supplement use when indicated is for children up to 16 years of age.<sup>51</sup>

All fluoride supplementation should be under the supervision of a physician or a dentist. See the [Figure](#) for fluoride supplementation guidelines.

### Fluoride Supplements and Breastfeeding

Providing prenatal systemic fluoride in amounts higher than obtained normally through water and food is not recommended because there is little indication that fluoride will confer meaningful systemic benefits to the developing fetus prenatally.<sup>60</sup>

Fluoride supplements are also not generally recommended for breastfed infants residing in fluoridated communities. Although the concentration of fluoride in breast milk is very low, many mothers combine breastfeeding with formula feeding and might be giving infants fluoridated water between feedings.

Registered dietitians should consider it part of their practice to inform pregnant women and parents of infants and young children about the guidelines for the use of fluoride supplements and refer clients to dental care providers when indicated.

### TOPICAL APPLICATION

Fluoride from mouth rinses, dentifrices, gels, foams, and varnishes are impor-

tant topical fluoride sources that are highly effective and can be easily administered in the school, home, or dental office setting.<sup>27,28,61-63</sup> They are meant to provide a consistent source of fluoride to increase the resistance to acid of the outer layers of tooth enamel throughout life, and are not meant to be swallowed for systemic effects.

For individuals at high risk of developing dental caries (especially those with special health care needs), concentrated fluoride solutions, gels, and varnishes are also effective when applied by dental professionals. Fluoride rinses also provided additional caries-preventive benefits for individuals with high caries levels and who also drank

fluoridated water and used fluoride-containing dentifrices.<sup>64</sup> The use of fluoride varnishes in school-based oral health programs for children as well as in private practice is increasing, as fluoride varnish is an effective and easily applied method for providing topical fluoride therapy.<sup>65</sup>

Fluoride products carrying the American Dental Association seal of approval on the product label have undergone extensive clinical testing to demonstrate their effectiveness and safety.<sup>66</sup> To reduce the risk of fluorosis in developing permanent teeth, children should not swallow oral care products meant for topical use. For this reason, the American Dental Association does not recommend the use of fluoride mouth rinses by children under the age of 6 years.<sup>67</sup> They recommend that children aged 2 to 6 years brush with a pea-sized amount of fluoride toothpaste only, and that children should be supervised while brushing and taught to spit out rather than swallow the toothpaste rinse or gel. Parents should consult with the child's dentist or physician before using fluoride toothpaste for children under 2 years. Parents and caregivers should judiciously monitor the use of all fluoride-containing products by children under the age of 6 years.<sup>68</sup>

Fluoride modalities protect adults and people of all age groups. Older adults and other vulnerable populations are especially benefited when their ability to receive dental care or their ability to practice good oral hygiene are not compromised. Because of the successes of the dental team and increased oral health literacy, many more adults keep their teeth. It is no longer a foregone conclusion that dentures are a part of aging. Many of these older adults have root surface exposure due to gum recession, for example. These surfaces are particularly vulnerable to decay and are a prime example of how fluoride can benefit older adults.<sup>69</sup>

## Topical Fluoride Indications through the Life Cycle

Indications for the use of fluorides are based primarily on levels of caries risk rather than age or other factors. An expert panel established by the American Dental Association Council on Scientific Affairs determined a system for caries risk assessment that is valid and reliable and that can be used to categorize

patients into low, moderate, and high caries risk.<sup>70</sup> The risk categories are based on the number and timing of the development of carious lesions and the presence or absence of risk factors. These risk factors include medication, radiation, or disease-induced dry mouth (xerostomia); poor oral hygiene or inability to perform proper oral health care; high levels of cariogenic bacteria; poor family dental health; genetic, developmental, or acquired dental defects; chemotherapy or radiation therapy; eating disorders; drug or alcohol abuse; cariogenic diet; irregular dental care; orthodontic treatment; or the presence of exposed root surfaces. The risk categories are as follows:

1. Low risk: All age groups—no incipient or cavitated primary or secondary carious lesions within the past 3 years and no other risk factors.
2. Moderate risk:
  - Younger than age 6 years—no incipient or cavitated primary or secondary carious lesions within the past 3 years, but the presence of at least one other risk factor.
  - Older than 6 years—any of the following:
    - one or two incipient or cavitated primary or secondary carious lesions in the last 3 years;
    - no incipient or cavitated primary or secondary carious lesions within the past 3 years, but the presence of at least one other risk factor.
3. High risk:
  - Younger than age 6 years—any of the following:
    - any incipient or cavitated primary or secondary carious lesions in the last 3 years;
    - presence of multiple factors that can increase caries risk;
    - suboptimal fluoride exposure;
    - xerostomia.
  - Older than 6 years—any of the following:
    - three or more incipient or cavitated primary or

secondary carious lesions in the last 3 years;

- presence of multiple factors that can increase caries risk;
- suboptimal fluoride exposure;
- xerostomia.

Preventive recommendations can then be made by qualified health professionals for fluoride use based on risk category.

Fluoride recommendations by level of risk are as follows: Individuals of all ages are encouraged to use fluoridated water and to brush with a fluoride-containing dentifrice. Fluoride dietary supplements should be used only when indicated (see earlier discussion).

Individuals of any age who have teeth and are at low caries risk will probably not receive additional benefit from professional topical fluoride applications. For these individuals, fluoridated water and fluoride toothpaste can provide adequate caries prevention. The decision whether or not to apply topical fluoride in these cases should be made by the practitioner and individual patient.

### Children younger than 6 years

**Moderate caries risk:** Children under the age of 6 years who have teeth and are at moderate caries risk, should have professional fluoride varnish applications twice a year.

**High caries risk:** The children at high caries risk should have fluoride varnish applications twice a year. There is some evidence that applications of fluoride varnish more often than twice a year can be more effective in caries prevention.

### Children and teens aged 6 to 18 years

**Moderate caries risk:** Children older than age 6 years and teens should have either professional fluoride varnish or fluoride gel applications twice a year, at the discretion of the dentist and patient.

**High caries risk:** Children older than age 6 years and teens who are at high risk for developing caries should have professional fluoride varnish applications two to four times a year or fluo-

ride gel applications twice a year, at the discretion of the dentist and patient. Again, there is some evidence that applications of fluoride varnish more often than twice a year can be more effective in caries prevention.

### Adults and older adults (aged 65 years and older)

**Moderate and high caries risk:** For people older than age 18 years, although there are no clinical trials to support recommending professionally applied topical fluoride varnish or gel, there is reason to believe that these products, applied two to four times a year, can be effective in preventing caries.

## FLUORIDE SAFETY

### Dental Fluorosis and Bone Health

Fluoride research of more than 65 years has shown that fluoride is safe and effective at the levels used for water fluoridation (0.7 to 1.2 mg/L). However, naturally fluoridated areas at a level  $\geq 2$  mg/L can put children 8 years old and younger at increased risk for dental fluorosis, and consumption of water with a fluoride content of 4 mg/L over a lifetime can increase risk for bone fractures.<sup>71</sup>

Fluorosis is hypomineralization of tooth enamel that results from excessive fluoride ingestion before tooth eruption in children (during enamel development).<sup>72-75</sup> Clinically, the appearance of fluorosis can range from hardly noticeable white spots to severe pitting and discoloration of teeth, depending on the dose, duration, and timing of fluoride intake. In recent years, there has been an increase in the prevalence of mild fluorosis in the United States and many developed nations,<sup>7</sup> attributable to a variety of factors, such as young children swallowing fluoride dentifrice, misuse of dietary fluoride supplements, use of powdered infant formula reconstituted with fluoridated water, and diffusion (“halo”) effect of increased fluoride from foods and beverages processed in fluoridated areas.<sup>50,76,77</sup> According to the Centers for Disease Control and Prevention, 32% of American children now have some form of dental fluorosis, with 2.45% of children having the moderate to severe stages.<sup>7</sup> Because fluoride can be toxic if consumed in excessive amounts, fluo-

ride products should be kept out of reach of small children.<sup>78</sup>

The Environmental Protection Agency (EPA) has jurisdiction over the amount of fluoride allowed in drinking water. The EPA has set an enforceable regulation for fluoride (called the maximum contaminant level [MCL]) at 4.0 mg/L or 4.0 ppm, a level at which no adverse health effects are likely to occur over a lifetime. The MCL is set in consideration of health goals, cost, benefits, and the ability of public water systems to detect and remove contaminants using suitable treatment technologies. The EPA has also set a secondary (nonenforceable) standard (secondary maximum contaminant level) for fluoride at 2.0 mg/L or 2.0 ppm to protect against cosmetic effects (such as the moderate tooth discoloration of fluorosis). Although not required to comply with secondary maximum contaminant levels, states can choose to adopt them as enforceable standards and must inform customers of the risk for dental fluorosis in children if the secondary maximum contaminant level is exceeded.<sup>79</sup> As a result of a review of new health and exposure data available on orally ingested fluoride conducted by the National Research Council of the National Academies of Science, in 2006 the National Research Council recommended that the EPA update its fluoride risk assessment to include new data on health risks and better estimates of total exposure. The report concluded that the present MCL of 4 mg/L was not protective for severe dental fluorosis and might not be protective for skeletal fractures, and that the EPA’s MCL goal of 4 mg/L should be lowered.<sup>80</sup> Lowering the MCL goal will prevent children from developing severe enamel fluorosis and will reduce the lifetime accumulation of fluoride into bone that the majority of the committee concluded is likely to put individuals at increased risk of bone fracture and possibly skeletal fluorosis, which are particular concerns for subpopulations that are prone to accumulating fluoride in their bone. The EPA has begun the process of determining whether or not to lower the maximum allowable level of fluoride in drinking water from the current 4 ppm. The review process is currently ongoing and has no definite time table for completion.

It was also reported that the preva-

lence of severe enamel fluorosis is very low (near zero) at fluoride concentrations  $< 2$  mg/L. Any increase in moderate enamel fluorosis at this level would only be a cosmetic effect, with no evidence of any other adverse health effects. It was recommended that studies of the prevalence and severity of enamel fluorosis should be done in US communities with fluoride concentrations  $> 1$  mg/L. Currently, the US Department of Health and Human Services and the EPA are in accord that the recommended level of fluoride in drinking water should be set at the lowest end of the current optimal range of 0.7 to 1.2 mg/L water to attain the benefits of tooth decay prevention while limiting unwanted health effects.<sup>79,80</sup>

These suggested changes in regulations are also currently undergoing a review process and have not been approved at this point. Once the EPA has established their guidelines, further recommendations can be made.

### ACADEMY EVIDENCE ANALYSIS LIBRARY SYSTEMATIC REVIEW OF FLUORIDE QUESTIONS

This section summarizes the results of a systematic review of the literature conducted using the Academy’s Evidence Analysis Process. In this process, an expert work group identified dietetics practice–related questions about fluoride and a systematic review of the literature was performed. The level of evidence provided the basis for a rating for each statement and a conclusion statement.

The literature review was conducted in March 2009. To identify and select articles for review, the National Library of Medicine’s PubMed database and the Cochrane Database of Systematic Reviews were searched for information on fluoride or sodium fluoride published in peer-reviewed journals in the past 10 years. The search was limited to English and included free living humans of all ages. All study designs except case studies were included in the search. Articles published from 1998 to 2009 with a sample size of at least 10 adults per study group and with a  $< 20\%$  dropout rate were searched. Studies were also identified by screening the reference lists of the selected articles. Identified articles were then excluded if they did not provide an answer that was directly related to the question.

The detailed search plan and results and information on the process and how the conclusions of the Fluoride Evidence Analysis Project were reported on the Evidence Analysis Library website.<sup>81</sup> The Academy uses Grades I, II, and III, for strong, fair, and weak levels of evidence. Grade IV designates expert opinion only; and Grade V indicates not assignable (because there is no evidence that directly supports or refutes the question).

Questions about fluoride that were analyzed through this evidence analysis process and the findings are as follows<sup>81</sup>:

### What is the relation between silicofluoride exposure and blood lead levels in children?

**Conclusion statement:** Water fluoridation with silicofluoride (but not sodium fluoride) can be associated with increased risk of elevated blood lead levels in children, especially those already at risk for lead exposure.

The overall strength of the available supporting evidence was determined to be **Grade III=fair**, indicating only limited evidence for a relationship between silicofluoride exposure and blood levels in children.

The American Dental Association and the Centers for Disease Control and Prevention indicate that all of the chemicals used in fluoridation meet safety standards.

### What is the relation between exposure to high levels of fluoride in drinking water and intelligence quotient (IQ) in children?

**Conclusion statement:** All four primary studies consistently found a negative relationship between chronic exposure to high levels of fluoride (>3.15 mg/L) and IQ in children when compared with children who live in areas with lower levels of fluoride in the drinking water (<1.0 mg/L). The meta-analysis also reported the same relationship in 12 of the 16 studies examined. One of the four primary studies found a statistically significant increase in proportion of children with IQ <80 when mean fluoride level in the water was 2.46±0.25 mg/L.

Application to US populations is hampered by several limitations:

- Fluoride levels are often confounded with levels of other known neurotoxins (such as arsenic) in the studies, as fluoride was naturally occurring.
- All populations studied were non-US settings (one Mexican and the rest Chinese); therefore, exposure levels and confounding factors can be quite different than in a US setting.
- Although none of the studies found an association between IQ and fluoride levels <1.0 mg/L, this research cannot be used to identify a safe upper limit.

As a result of these findings, the strength of the available supporting evidence was determined to be **Grade III=fair**, indicating only limited evidence for an association between fluoride intake and IQ.

### What are the effects of fluoride exposure (intake) on the renal system at different levels (among different age groups)?

**Conclusion statement:** Research on the relationship between ingestion of fluoride and renal function is limited by several factors including:

- most of the studies were of neutral or negative methodological quality;
- few studies report precise individual levels of fluoride ingestion; and
- none of the studies were of US populations.

The research suggests that ingestion of lower levels (conservatively <1 to 1.5 ppm) of fluoride in healthy subjects is not associated with renal impairment.

The very limited research does suggest an association between ingestion of higher levels (2.2 ppm in a single study, although there is no clear definition of higher levels obtainable from the research) of fluoride in drinking water and fluorotoxic effects in subjects with impaired renal function. However, the research suggests that this association might be the result of impaired fluoride excretion by subjects who already have some form of renal compromise.

As a result of these findings, the strength of the available supporting evidence was determined to be **Grade**

**III=fair**, indicating only limited evidence for an association between fluoride intake renal system effects.

In summary, there is very little evidence to support any of the concerns voiced in these questions. Registered dietitians should feel well supported in allaying fears about harmful side effects of fluoride when provided in recommended amounts.

### THE ROLE OF DIETETICS PRACTITIONERS

Fluoride provides important health benefits throughout the life cycle and should be promoted by dietetics practitioners throughout their practices. Dietetics practitioners work in a wide variety of practice arenas (eg, inpatient, ambulatory, community, public health, media, industry) with clients of all ages and are therefore in a better position than many other health professionals to advocate for the appropriate use of fluoride. Dietetics practitioners should become knowledgeable about fluorides<sup>82</sup> and routinely promote and monitor the appropriate use of systemic and topical fluorides in vulnerable groups, including older adults and especially children and adolescents. Dietetics practitioners should recommend that children have their first dental visit within 6 months of eruption of the first tooth and no later than 12 months of age.<sup>83,84</sup> They should also monitor fluoride use by obtaining information about the fluoridation of local water supplies from state departments of public health and referring children to dental professionals when indicated. The Figure provides suggested age-specific fluoride recommendations. Dietetics practitioners should also add their voices as strong advocates for community water fluoridation legislation whenever it is a ballot issue. Toward this end, alliances and referral systems among dietetics practitioners, dental hygienists, and dentists need to be strengthened in the pursuit of optimal oral health.

When fluoride is provided in optimal amounts, it can potentially convey major dental health benefits to all age groups.<sup>68</sup> Fluoridation of public water supplies has been recognized as one of the most effective dental public health measure in existence.<sup>4,85</sup> Still, approximately one third of the US population on public water systems fails to receive the maximum benefits possible from



community water fluoridation for a variety of reasons. Fluoridated water and dentifrices are the mainstays of fluoride delivery for all age groups.<sup>29</sup> Access to dental care is an ongoing concern. *Healthy People 2020* has a continued goal to promote interventions such as fluoride to reduce tooth decay.<sup>86</sup> Dietetics practitioners can be strong advocates for the appropriate use of fluoride as an integral component of total health promotion. The Academy of Nutrition and Dietetics strongly reaffirms its endorsement of the use of systemic and topical fluorides, including water fluoridation, as an important health-promotion measure.

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