Overall risk assessment of pediatric dental fluorosis in the United States

Yekaterina Leonidovna Manyoky

The University of Toledo

Follow this and additional works at: http://utdr.utoledo.edu/graduate-projects

This Scholarly Project is brought to you for free and open access by The University of Toledo Digital Repository. It has been accepted for inclusion in Master's and Doctoral Projects by an authorized administrator of The University of Toledo Digital Repository. For more information, please see the repository's About page.
Overall Risk Assessment of Pediatric Dental Fluorosis in the United States

Yekaterina Leonidovna Manyoky

The University of Toledo

2011
Dedication

To my husband and my mom, for their constant love and support.
Acknowledgements

I could not accomplish this project without Dr. Fink, my advisor. Thank you for all your help.
Table of Contents

Introduction ......................................................................................................................................5
Background ......................................................................................................................................9
Fluorosis Risk Assessment due to Water Fluoridation .................................................................12
Fluorosis Risk Assessment due to Topical Fluoride Exposure .......................................................16
Fluorosis Risk Assessment due to Supplementation ......................................................................19
Fluorosis Risk Assessment due to Infant Formula ..........................................................................22
Risk Overview due to Overall Fluoride Exposure ........................................................................24
Conclusions ....................................................................................................................................27
References ......................................................................................................................................29
Tables .............................................................................................................................................33
Figures ...........................................................................................................................................34
Abstract .........................................................................................................................................35
Introduction

Pediatric dental fluorosis is the reason caries-preventative effects of fluoride were discovered. Fluorosis is a hypomineralization of the enamel due to fluoride overexposure during tooth development, most susceptible time being 15-24 months for boys and 21-30 months for girls. ("CDC: Recommendations for Using Fluoride to Prevent and Control Dental Caries in the United States," 2001) The severity of fluorosis depends on timing, amount, and duration of exposure and ranges from opaque, white patches or streaks on teeth to brown discoloration in more severe form. The only time that the enamel is susceptible to fluorosis is during enamel development up to age eight. After that, fluorosis is no longer a concern. ("CDC: Recommendations for Using Fluoride to Prevent and Control Dental Caries in the United States," 2001)

There have been many studies conducted to uncover and better understand enamel fluorosis development and fluoride metabolism by the human body, but to this day it is still uncertain. The studies cumulatively theorize that fluoride builds up in enamel and inhibits proteinases that normally break up the larger amelogenin molecules. Because amelogenins are not broken down, they accumulate and interfere with crystal growth and structural appearance of the enamel. (Browne, Whelton, & O'Mullane, 2005) Increased amounts of fluoride in enamel combined with increased protein may be the major factors responsible for the protective effects against acid which causes dental caries. (Waidyasekera, Nikaido, Weerasinghe, Wettasinghe, & Tagami, 2007)

With the current recommended water fluoride levels in the United States, most of the fluorosis commonly seen is of mild or very-mild nature manifested as opaque white spots or streaks on the teeth. Many do not even recognize that there is anything wrong with their child’s
teeth. According to a study by Griffin et al., only about 2% of U.S. schoolchildren may have esthetically objectionable fluorosis that may interfere with quality of life and self-esteem. (Griffin, Beltran, Lockwood, & Barker, 2002) In a different study conducted in Newburgh and Kingston, New York, researchers looked at the intra-oral distribution of fluorosis. Their analysis revealed that the severity and frequency of enamel fluorosis was lower on upper anterior maxillary teeth compared with posterior teeth in a fluoridated area. (Kumar, Swango, Haley, & Green, 2000) This means that much of the fluorosis is on the posterior teeth, which are not readily observed when talking or smiling and, therefore, does not constitute a great concern esthetically.

Another study took the perspective of dental students at the beginning and at the end of their training. The findings indicate that fourth-year dental students had a more favorable reaction to esthetics of mild dental fluorosis than when they were first-year students. (Levy, Warren, & Jakobsen, 2002) The authors explained that perhaps the difference lies in the fact that mild dental fluorosis is not a true disease. It has no morbidity and it does not progress over time, therefore after learning about its harmless nature, the students became more accepting of the look. (Levy, Warren, et al., 2002) Interestingly, the authors compared first-year dental students to the esthetics-concerned patients, and they also compared the fourth-year dental students to the dentists, who tend to be less concerned with mild fluorosis than their patients. (Levy, Warren, et al., 2002)

Yet another study looked at teenagers’ perceptions of dental fluorosis. They found that teens can distinguish fluorosis of different levels at a variety of distances. (Edwards, Macpherson, Simmons, Harper Gilmour, & Stephen, 2005) Not surprisingly, fluorosis is less detectable in the distance than up close. The study concluded that the esthetic perception of fluorosis should be
studied in the context of the whole face and also from a distance, since that it how people will actually be encountering it. (Edwards, et al., 2005) In a literature review of esthetic perceptions of dental fluorosis, the major conclusion was that present efforts should be concentrated on the correct and appropriate use of fluorides for prevention of dental caries and avoidance of moderate to severe fluorosis, which is rare in the United States anyway. (Chankanka, Levy, Warren, & Chalmers, 2010) The oral health related quality of life was not found to be affected by mild and very-mild fluorosis, which comprises the majority of fluorosis in the United States. (Chankanka, et al., 2010)

Although pediatric dental fluorosis of mild nature seems to be treatable and not esthetically problematic, preventing it in the first place would be the best option. In an analysis of the survey data obtained from the Iowa Fluoride Study subjects, Hong et al. report that daily fluoride intake of <0.04 mg F/kg of body weight (BW) had less than 20% probability of developing fluorosis and the fluorosis that did develop was mild. (L. A. Hong, Levy, Warren, Broffitt, & Cavanaugh, 2006) Yet, even if that value is made the cutoff point for early-erupting permanent teeth, it will still be different than a “threshold” definition because there is so much variability among children. The exact same fluoride exposure of two individuals may reveal different results due to susceptibility. (L. A. Hong, et al., 2006) Due to lack of uniformity in response to fluoride, it is extremely difficult to define actual critical levels of fluoride intake that would constitute fluorosis development. (L. A. Hong, et al., 2006)

The conundrum is that dental caries rates are low, but fluorosis rates are climbing. The purpose of this paper is to analyze the different sources of fluoride exposure in children, to assess the risk for developing dental fluorosis pertaining to the exposure, and to determine whether everything possible is being done to minimize that risk while keeping the caries-preventative
properties to the maximum. Water fluoridation accounts for a major source of exposure to fluoride. There are other sources of exposure as well, such as fluoride supplements, toothpaste, mouthwash, infant formula, and food prepared with fluoridated water. In this paper, sources of fluoride exposure will be examined individually and then the combined exposure will be discussed at the end.
Background

Since the major source of fluoride exposure in the U.S. comes from water, the issue of water fluoridation has been studied and discussed for years. It has been the topic of debate in many countries around the world. Some countries have started to implement water fluoridation, some started and then discontinued, and some have never tried it in the first place. Water fluoridation means adding a controlled amount of fluoride to the community water supplies in order to glean its caries-preventative power. There are estimations that more than 300 million people in 39 countries use fluoridated water supplies. In the United States, more than 170 million people or 67% of the population have fluoride added to their water. (Pizzo, Piscopo, Pizzo, & Giuliana, 2007) There is a wide spectrum of opinion on mass water fluoridation due to its ethical implications. There are people that consider fluoride a medicine used to prevent a disease (dental caries) and if it is a medicine, people’s autonomy is compromised if they have not been consulted before beginning fluoridation.

It all started with Dr. Frederick McKay, who is now known as the “Father of Communal Fluoridation.” He went to dental school in Pennsylvania and moved to Colorado Springs, Colorado to practice. When Dr. McKay looked at the teeth of children native to Colorado Springs, he noticed that most of them had mottled enamel and many had permanent brown stains on their teeth, which they called “Colorado Stain.”(Maloney & Maloney, 2009) He became fascinated with this phenomenon and began to study the subject. From looking at other areas of the country where the mottling was not as common, McKay began to suspect that something in the water was responsible.

He summarized his findings in 1917 and then in early 1930’s with the help of H.V. Churchill, the chief chemist at the Aluminum Company of America, McKay was finally able to
deduce that the water had high amounts of fluoride, which correlated with the tooth
discoloration. Another observation he made was that the children with mottled stain had a
significantly lower amount of dental caries compared with the children who did not have the
tooth discoloration. This led him to eventually recognize that some fluoride in the water was a
protective factor for dental caries development, while a high concentration of fluoride was
responsible for permanent mottling and staining of the tooth enamel. (Maloney & Maloney,
2009)

The next big step toward modern fluoridation came in 1950, when the Chief Dental
Officer of the United States Public Health Service issued a policy statement to the American
Dental Association encouraging fluoridation of public water supplies upon approval of state and
local authorities. (Lennon, 2006) The recommendations were mainly based on research
conducted by H. Trendley Dean and his colleagues working from the National Institutes of
Health (NIH). Dean worked on several epidemiologic studies that investigated this new claim
that adding fluoride to the water decreases dental caries incidence. The studies confirmed the
hypothesis, but Dean also found that if fluoride concentration in the water was 1.0 parts per
million (ppm) or less, dental fluorosis was either absent or very mild, while if the concentration
was higher, dental fluorosis prevalence became higher and more severe. (Pizzo, et al., 2007) By
1960, water fluoridation became widely popular and by 2002, 46 of the 50 largest cities in the
U.S. were fluoridated. (Lennon, 2006)

Having discovered the caries-preventive power of fluoride, which naturally exists in the
earth’s crust, scientists began to think about methods of exposure other than water fluoridation.
Some people lived in villages and small towns where natural levels of fluoride in the water were
lower than the optimal levels set by the researchers. Fluoride supplements were developed to
help these people increase fluoride intake. Then, fluoride also made its way into toothpaste and infant formula. Before one knew it, fluoride was everywhere. The incidence of dental caries dropped dramatically, but the incidence of dental fluorosis slowly started to climb.

In the modern world of great media exposure and mass supplementation of different vitamins and minerals, the problem becomes overexposure. How much is too much, how much is just enough, how much is too little? The biggest problem with adding fluoride to various sources is that to this day, nobody truly knows how much fluoride exposure is enough to prevent dental caries, while avoiding any negative effects of overexposure. There are guidelines and estimates, but nobody can accurately monitor how much water a child drinks, how much toothpaste he swallows, how much food he eats that was prepared with fluoridated water, and what the overall exposure actually is. It is difficult to monitor and therefore a closer look at the risk of fluorosis development is needed.
Fluorosis Risk Assessment due to Water Fluoridation

When water fluoridation first began, many studies focused on proving the cariostatic nature of fluoride in the water and they had great success. These studies reported that caries incidence was on the decline fifty to seventy percent due to fluoridation. On the other hand, as time went on and by mid-1980’s the relative effectiveness rate of water fluoridation went down, while the fluorosis rates began to increase. (Pizzo, et al., 2007) The new analysis of the earlier data supplied by the epidemiological studies is supporting the current view that the mechanism of action of fluoride is actually post-eruptive topical and not really systemic as previously thought. Some findings have shown that fluoride may interfere with acid formation by bacteria that causes enamel destruction and dental caries. (Pizzo, et al., 2007) Frequent exposure to low concentrations of fluoride in the oral cavity is essential for caries prevention and control, while systemic fluoride exposure benefits are minimal. (Pizzo, et al., 2007)

In European countries where community water fluoridation was never implemented, the lifetime dental caries experience has decreased over seventy-five percent. This finding coincides with the fact that fluoride-containing toothpastes were introduced in the early 1970’s as well as other fluoride-containing products since then. (Pizzo, et al., 2007) If there was such a tremendous response to many sources of topical fluoride, water fluoridation may prove one day to be unnecessary and obsolete. In the United States, water is one of the major sources of exposure to fluoride. Combined with other sources, it can be a reason for overexposure to fluoride in early childhood and a risk factor for fluorosis. If studies are showing that water fluoridation is no longer a necessary factor in caries prevention, it may be wise to stop it and thus, decrease the exposure of young children to more fluoride than necessary.
In a case study done in a rural community in western Washington, fluoride exposure was evaluated due to some reports of high levels of fluoride in private well water. The island of San Juan, Washington is supplied by non-fluoridated municipal water and many private wells. After testing the water and examining for dental fluorosis, it was found that the opposite of the past reports was true. The water fluoride levels ranged from 0.08-1.30 mg/L, and were below the recommended amount for the most part. The fluorosis rate was lower than the national average as well at 18.8%, once again proving the direct link with water fluoride exposure and fluorosis.(Graves, Daniell, James, & Milgrom, 2009) According to the authors, “Neither drinking water nor supplemental sources of fluoride accounted for the small number of detected children with dental fluorosis.”(Graves, et al., 2009) It may have been due to genetic variability and susceptibility to fluoride.

In addition, the recommended “optimal” daily fluoride intake of 0.05-0.07 mg/kg of body weight is mostly based on fluoridated water and preventing caries, but does not really focus on avoiding fluorosis or consider exposure from topical sources.(Warren et al., 2009) Fluoridated toothpaste came on the market after the recommended amount in the water was established and that amount has not changed since then until just recently. On January 7, 2011, The U.S. Department of Health and Human Services (HHS) along with the U.S. Environmental Protection Agency proposed a change in the recommended fluoride concentration in public water supplies. The recommended concentration would be 0.7mg/L, which is the lowest part of the previous recommended range of 0.7-1.2mg/L. ("HHS and EPA Announce New Scientific Assessments and Actions on Fluoride," 2011) Griffin et al. suggest that the lifetime benefits of caries prevention need to be weighed against the low possibility of esthetically unpleasing teeth and perhaps the solution is to lower the fluoride content in toothpaste and institute educational
programs for parents instead of changing anything in the fluoridation policy. (Griffin, et al., 2002)

Some places in the world, do decide to stop water fluoridation though. A couple of communities in British Columbia, Canada stopped fluoridating their water supplies in 1992. (Clark, Shulman, Maupome, & Levy, 2006) Then, in 2002-03, children’s teeth were examined for presence of fluorosis. The prevalence and severity of fluorosis decreased significantly after stopping fluoridation. The prevalence decreased from 58% to 24%. (Clark, et al., 2006) The problem with this result is that during the years after cessation of fluoridation, the use of supplements and fluoride toothpaste also decreased, making it difficult to tell exactly how much of an effect each source of exposure had on lowering the fluorosis rate. (Clark, et al., 2006) Conversely, it is obvious that limiting fluoride exposure from multiple sources does decrease the risk of fluorosis. Another limitation of the study was that they did not address dental caries. It would be helpful to know whether the caries rates increased or stayed the same through the years after cessation of water fluoridation.

Also, more and more people are starting to drink bottled water, which typically has a low fluoride concentration. One study looked at the effect of bottled water use on caries prevalence. Once again, the participants of the Iowa Fluoride Study were used as subjects starting at the age of 6 and continuing until their mixed dentition exam a few years later (ages vary). (Broffitt, Levy, Warren, & Cavanaugh, 2007) Bottled water users were considered children who consume at least 25% of their water intake from bottled water. Only about 10% of the subjects were bottled water users. The results of the study found no significant differences in dental caries prevalence or incidence between people that used bottled water and those who did not. (Broffitt, et al., 2007) Of course, there are serious limitations to the study, but it is interesting to see that
the caries rates did not go up even though fluoride exposure decreased at least slightly. The study did not address fluorosis since they used older children as subjects, but it would have been interesting to see if bottled water use in younger children decreased the incidence of dental fluorosis.

Taking into consideration all of the evidence and studies done, there are a few options regarding water fluoridation that may prove to be beneficial. One option is to discontinue water fluoridation altogether since other countries that have never had fluoridated water have low caries rates due to other sources of exposure. However, United States prides itself on water fluoridation and will not be willing to discontinue it. Another option is to at least lower the concentration of fluoride in the water, which the United States has proposed in 2011. However, only time will tell if a concentration reduction will be enough to significantly influence fluorosis incidence.
Fluorosis Risk Assessment due to Topical Fluoride Exposure

Sources of topical fluoride exposure include toothpastes (dentifrices), mouth rinses, and gels/varnishes that the dentist applies directly to the tooth surface. Topical fluoride exposure only becomes a problem when a child ingests the fluoride. There are several aspects to this problem. First, most children’s and adult toothpastes contain the same amount of fluoride and children’s toothpaste tastes better, which in turn becomes an inviting factor to swallow it. (Dincer, 2008) Secondly, the swallowing reflex in children under 6 years old is not fully developed and they swallow 25-33 percent of the toothpaste without trying. (Dincer, 2008) Also, if the child is very young, he cannot spit out the toothpaste when he is told to do so because he might not understand what is being asked of him. Another aspect of the problem is that many times there is a lack of parental supervision while a child is brushing his teeth.

Lastly, advertisements of toothpaste usually show the whole length of the toothbrush being covered by the paste, visually stimulating people to do the same. After watching a toothpaste commercial, one would not know to put only a pea-sized dollop of toothpaste on the brush as is recommended. Using more than the recommended amount of toothpaste increases the amount being swallowed and poses a serious risk for fluorosis development. Centers for Disease Control and Prevention found a nine percent higher prevalence of enamel fluorosis in American children than it was twenty years earlier in a similar survey. (Dincer, 2008)

The single most important way to decrease fluorosis risk is to decrease exposure through parent education. Many parents simply do not realize that toothpaste poses a risk to their children’s teeth. The usual notion of “the more, the better” frequently takes over and parents do not understand the problem with swallowing fluoride since it is common knowledge that fluoride has cariostatic attributes.
A 2010 Cochrane Review concluded that there is an increased association between dental fluorosis and starting to use fluoridated toothpaste before 12 months of age. Also, there is an inconsistent association with fluorosis if toothpaste use started before 24 months of age. (Wong et al., 2010) However, the authors’ overall analysis is that much of the evidence is weak and unreliable, with majority focusing only on mild fluorosis. The two randomized controlled trials (RCTs) available state that higher concentrations of fluoride in toothpaste are associated with an increase in fluorosis, but cross-sectional surveys did not support this conclusion. (Wong, et al., 2010) The final advice was that if fluorosis is of concern, young children should use toothpaste with fluoride level lower than 1000 ppm. (Wong, et al., 2010)

Conversely, in a different review, which considered toothpaste fluoride concentrations and caries prevention in children and adolescents, the conclusions were somewhat different. According to the placebo-controlled trials, caries-preventive effects are only statistically significant at toothpaste fluoride concentrations of 1000/1055/1100/1250 ppm and above. (Walsh et al., 2010) The lower concentrations of fluoride in toothpaste proved not to be significant, but similar to the placebo in caries prevention. A limitation of the review is that there are much fewer studies of the lower fluoride concentration toothpastes. (Walsh, et al., 2010) Although the risk of fluorosis must be considered, toothpaste recommendation stays at 1000 ppm for children under age 6 and then goes up to 1500 ppm for older children. (Walsh, et al., 2010) In addition, even though evidence suggests that low-fluoride toothpaste by itself is not enough to prevent caries, it may be enough when the rest of the exposure is accounted for. By using the low-fluoride toothpaste for young children whose swallowing reflex is not fully developed, the overall fluoride exposure can be significantly decreased. Therefore, the risk for fluorosis development can be decreased as well.
It is obvious that in order to decrease fluorosis prevalence, fluoride exposure needs to be decreased. This can be done by several methods involving topical fluorides. Since most of the problems arise from swallowing high-fluoride toothpastes, parental awareness and education on the topic needs to increase. Supervision is critical. Another option is to start using low-fluoride toothpaste for children, thus minimizing the fluoride exposure by swallowing. This option seems to be less favorable because it is now known that most of the benefit of fluoride is from topical exposure. There are also fluoride-free toothpastes available, which can be used during the first two years of life in order to practice tooth-brushing with the child and teach him not to swallow the toothpaste as much as possible. Then, when switching to fluoridated toothpaste, brushing teeth without swallowing will perhaps be easier. For other topical fluorides, such as mouth-rinse, gels, and varnish, great caution is warranted if these methods of exposure are deemed necessary.
Fluorosis Risk Assessment due to Fluoride Supplements

Fluoride supplements are routinely given to children whose fluoride intake is deemed to be below the recommended level of 0.05-0.07mg/kg BW or whose caries risk is high. The use of fluoride supplements in the form of drops, tablets, or lozenges, began before the introduction of fluoride toothpaste to the market and used to be an important source of fluoride exposure. In the modern day United States, where fluoride exposure is abundant, the further need for fluoride supplementation should be reexamined.

In a recent systematic review commissioned by the American Dental Association Council on Scientific Affairs, a team of scientists looked at different studies done on the efficacy and dangers of fluoride supplements. They have found the evidence pertaining to caries prevention in the primary teeth to be weak and inconsistent; however, there was evidence that supplements prevent dental caries in permanent teeth. Fluorosis still remains the major side effect and ranges from mild to moderate in nature. (Ismail & Hasson, 2008) One of the studies found that the use of fluoride supplements during the first two years of a child’s life increased the prevalence of fluorosis when compared with children who did not use supplements. (Ismail & Hasson, 2008)

As far as dental caries are concerned, the review found that there was little evidence that supplements prevent caries in the first three years of life, but there is substantial evidence that they do prevent caries in school-aged children. (Ismail & Hasson, 2008)

The overall conclusion of the systematic review was that the risk of fluorosis from supplement use should not be dismissed and accepted as inevitable. The use of topical fluorides, when used correctly, can provide the same caries-preventative benefits without a significant systemic exposure and no chance of developing fluorosis. (Ismail & Hasson, 2008)
Another difficulty with fluoride supplements is knowing how and when to use them correctly. In a recent study, researchers tried to assess whether family physicians and pediatricians are prescribing fluoride supplements in accordance with the current recommendations (Table 1) from the Centers for Disease Control and Prevention (CDC). (Sohn, Ismail, & Taichman, 2007) The CDC guidelines state that supplements should be reserved for children “who are at high risk of dental caries and whose primary drinking water has low fluoride levels.” ("Recommendations for Using Fluoride to Prevent and Control Caries in the United States," 2001) The study sent out a survey where two clinical cases were presented, one with a high risk for caries and one with low risk. Family physicians and pediatricians were supposed to analyze the cases and answer whether they would prescribe a supplement and what other guidelines they would give to the parents. The results indicated that physicians usually follow existing fluoride supplementation guidelines, but they do not often consider a child’s caries risk status. They mostly base the decision on whether the drinking water is fluoridated. Therefore, if children with low caries risk are taking prescribed fluoride supplements, they are being exposed unnecessarily. (Sohn, et al., 2007)

Sohn et al. found that in their survey of family and pediatric physicians, the doctors recommended the use of fluoridated toothpaste at a much lower rate than was expected. Only 75% of family physicians and 60% of pediatric physicians said they would recommend brushing with fluoride toothpaste. Their data also suggests that physicians are very much aware of the fluorosis risk posed by swallowing fluoride-packed children’s toothpaste, but the risk posed by fluoride supplements seems to be less known. (Sohn, et al., 2007) According to the authors of the study, physicians who designated fluoridated toothpaste as a very effective way to prevent caries only made up the minority. Physicians need more training to effectively identify children’s caries
risk in order to make wiser decisions on whether or not to prescribe supplements. (Sohn, et al., 2007)

A review published in 2004 for the U.S. Preventative Services Task Force examined the role of the physician in preventing dental caries in preschool children. The review concluded that supplements and fluoride varnish were effective interventions for dental caries in the primary care setting. However, there is enough evidence to suggest that physicians’ consideration of a child’s total fluoride exposure is incomplete. Prescribing fluoride supplements while underestimating exposure surely puts a child at risk for developing dental fluorosis. (Bader, Rozier, Lohr, & Frame, 2004) This is important because physicians serve as the sole source of medical contact for a long time before the child ever sees a dentist for the first time. Using supplements incorrectly could be attributed to about thirteen percent of cases of dental fluorosis in fluoridated areas. (Bader, et al., 2004)

The current fluoride supplementation schedule could be considered a risk factor for dental fluorosis, but other sources of exposure are more dangerous than supplements. It is very difficult for researchers to estimate the actual fluoride exposure of each child, and it is even more difficult for physicians. The supplementation schedule is based on whether the water is fluoridated on not. The recommendations do not take into account the overall exposure and therefore, can be unnecessarily putting children at risk for fluorosis. With fluorosis on the rise, physicians and dentists should be more cautious about prescribing supplements to children who actually need them rather than to any child living in a non-fluoridated area.
Fluorosis Risk Assessment due to Infant Formula

Infant formula in the United States may be a potential risk factor for developing enamel fluorosis in children. However, it appears that the powdered infant formula itself does not constitute a major source of fluoride exposure, but it is the fluoridated water that it is reconstituted with that provides the biggest exposure. The concentration of fluoride in the powdered formula used to be higher, but in 1979, infant formula manufacturers voluntarily lowered the content of fluoride in their products to 0.03-0.34 ppm (breast milk contains 0.02 ppm). (Hujoel, Zina, Moimaz, & Cunha-Cruz, 2009) According to the guidelines established by the Institute of Medicine in 1997, the tolerable upper intake levels are 0.7mg/day from birth to 6 months, and 0.9mg/day from 7 to 12 months.(Hujoel, et al., 2009) Taking into consideration that the water fluoride concentration usually ranges from 0.7-1.2 ppm, it is easy to go above the upper tolerable amounts, beyond which fluorosis is difficult to avoid.

The American Dental Association’s advice to parents who are concerned with the issue of fluorosis is to use non-fluoridated water to reconstitute the formula or use ready-to feed formula to lower the fluoride exposure of their infants. (Hujoel, et al., 2009) Ready-to-feed formula is more expensive than powdered and getting non-fluoridated water is done mostly through bottled water. Although most bottled water has low fluoride levels, bottled water companies do not report fluoride concentration on the label, making it difficult to make sure to choose one with low fluoride concentration. In addition, many parents do not know much about fluoride and the danger it might pose to their children, since the issue is not highly publicized and parent education on the topic is not widely discussed. As the prevalence of fluorosis increases, and fluoride exposure seems to be most important in the first 2 years of life, infant
formula reconstituted with fluoridated water remains a huge risk factor for fluorosis development. (L. Hong et al., 2006)

A systematic review conducted by Hujoel et al. (2009) gives some valuable suggestions on how parents and the government could protect children from developing dental fluorosis unnecessarily. One suggestion is that the Institute of Medicine could develop formula use guidelines so that the upper tolerable amounts are not exceeded. Another suggestion is to develop “biological normality” and have formulas with the same fluoride concentration as breast milk and mandate bottled water companies and infant formula companies to report fluoride levels on their labels, so that it is easier for parents to make informed choices.
Risk Overview due to Overall Fluoride Exposure

Besides the different venues of fluoride exposure early on, scientists have noticed that, as with everything else in life, genetic predisposition can play an important role in determining the severity of fluorosis a child gets. (Verkerk, 2010) There is individual biological variation among children, such as the timing of tooth eruption. There is much variation among children with apparently similar fluoride exposures too, so it very difficult to come up with standards that will not cause anyone to develop fluorosis, while maximally protecting from caries.

In a recently conducted systematic review of exposures associated with fluorosis, it was found that the greatest risk posed during ages 3 to 9 months was from powdered infant formula and beverages with added water, and during ages 16 to 36 months, the greatest risk was from dentifrice or the combination of both beverages and dentifrice. (Levy, Broffift, Marshall, Eichenberger-Gilmore, & Warren, 2010) Data gathered by the review supports the hypothesis that “high fluoride intake from beverages is a primary contributor to dental fluorosis of permanent maxillary incisors.”(Levy, et al., 2010)

A different study measured primary tooth fluorosis and fluoride intake during the prenatal period and the first 12 months of life. This study used mothers and children participating in the Iowa Fluoride Study as the subjects. The results indicated that each of the time periods studied (prenatal, 6-week to 3-month, 3-6 month, and 9-12 month) had significant association with dental fluorosis. The prevalence of fluorosis was most strongly associated with the period of 6-9 months. This is generally the time of the primary second molar early maturation stage. (Levy et al., 2002) There were, of course, considerable differences between individuals concerning eruption time and tooth development, which points to the fact that individual “most critical periods” may be before or after the set time frame. (Levy, Hillis, et al., 2002) In spite of the
individual variability, however, it may prove prudent to monitor a child’s fluoride intake more closely during the 6-9 month period. This is typically the age at which more foods and beverages are introduced to the child’s diet and less breastfeeding/formula use occurs. (Levy, Hillis, et al., 2002)

Primary tooth eruption is also occurring around this time frame. Another study’s results showed a strong association between mostly mild primary and permanent tooth fluorosis prevalence. (Levy, Warren, Broffitt, & Kanellis, 2006) Therefore, if primary tooth fluorosis is noted, it can be used as a predictor of permanent tooth fluorosis and as an early warning sign that the child may be ingesting too much fluoride. This sign could perhaps serve as an alert to start closely monitoring fluoride exposure of the child and decrease it to avoid the permanent tooth fluorosis. (Levy, et al., 2006) Yet, primary tooth fluorosis cannot be used as the only source of warning since permanent tooth fluorosis occurs without primary tooth fluorosis “relatively frequently”. (Levy, et al., 2006) Overall, however, primary fluorosis does seem to be a good predictive tool.

A study done in Australia can serve as an example for possible application in the United States. The dental fluorosis rate in Australia was climbing and the policymakers decided to try some measures to decrease fluoride exposure. They decided to change recommendations for fluoride supplement and toothpaste use. New recommendations discouraged the use of supplements in children altogether regardless of fluoridation status (set at 0.85mg/L in fluoridated communities), but set new guidelines for dentists who could prescribe supplements if they felt it was warranted. (Riordan, 2002) New recommendations also encouraged the use of low fluoride toothpaste and wide-circulated advice to use small quantities and supervision to minimize swallowing of the toothpaste. After the change in recommendations, the prevalence of
dental fluorosis was substantially reduced when re-examined ten years later. There was also no significant impact on dental caries prevalence. (Riordan, 2002) The author suggests that other communities should try limiting discretionary fluoride intake in order to lower unnecessary fluorosis but still prevent caries.

Even in the United States, water fluoridation discontinuation did not prove to be disastrous. An 11-month water fluoridation break in Durham, NC lowered fluorosis rates significantly, but did not affect the caries rates. The study showed that even a small decrease in fluoride exposure through water fluoridation can have a big effect on fluorosis prevalence. (Burt, Keels, & Heller, 2000) There is sufficient evidence to prove that overall systemic fluoride overexposure is the cause for fluorosis development. Exposure can be decreased in a variety of ways and unnecessary risk should be eliminated.

Throughout the years, there were things other than fluoride that people tried to link to fluorosis prevalence. For example, one such thing was amoxicillin use during infancy. A study was done to see if there is a potential association, but the results failed to show a connection. (L. Hong et al., 2004) The only thing that is known with certainty to cause fluorosis is fluoride. Fluoride exposure can come from unexpected sources, however. One such source is tea. A study was done to see how much fluoride different tea and herbal infusions contain. Black tea, in general had the most fluoride in it; herbal tea had the least. The study concluded that drinking certain types of tea in large quantities can be a major source of fluoride exposure. (Malinowska, Inkielewicz, Czarnowski, & Szefer, 2008) Certain cultures drink more tea than others and if young children are drinking tea like their parents, it can be considered a risk factor for developing dental fluorosis and perhaps should be surveyed at physician/dentist visits.
Conclusions

Overall evidence proves that dental fluorosis depends on the total fluoride ingestion by the child. However, the quality of evidence in the entire area of dental fluorosis research is low because the total amount of fluoride ingested is very difficult to calculate accurately and much individual variation is present. Yet, even with poor evidence, it is clear that lowering fluoride exposure will lower fluorosis rates.

In order to decrease fluoride exposure from fluoridated water, the U.S. has proposed a reduction of the recommended concentration to 0.07mg/L, but only time will tell with certainty whether it will be enough to make fluorosis rates drop. To decrease the fluoride exposure from dentifrice, parents need to use a pea-sized amount and smear it into the bristles in order to avoid portions of the paste falling off of the brush inside the child’s mouth, triggering him to swallow the delicious-tasting children’s toothpaste. Parental supervision is still essential. (Levy, et al., 2010) Also, it might prove to be beneficial if the FDA made it a requirement to warn people in toothpaste advertisements that children and adults should use only a pea-sized amount and show the correct amount so that people can visually retain the image. Supplements should be avoided unless the child is at a high risk for caries and the physician or dentist is thoroughly convinced that it would be beneficial. Good oral hygiene habits should be emphasized instead of supplementation. Since infant formula itself does not really present a risk, it should be reconstituted with non-fluoridated water so that it can get as close as possible to the levels in breast milk.

Pediatric dental fluorosis can be avoided if people become more aware of it and start taking precautions against overexposure. Even though esthetic appearance of mild fluorosis does not seem to be really bothersome, it is still unnecessary. It is encouraging to see policymakers
recognize the increasing prevalence of fluorosis and try to do something to lower it. Time will
tell if more exposure-reducing measures will be needed in the future.
References


Riordan, P. J. (2002). Dental fluorosis decline after changes to supplement and toothpaste regimens. *Community Dentistry and Oral Epidemiology, 30*(3), 233-240.


and adolescents. *Cochrane Database of Systematic Reviews*(1), CD007868. doi:10.1002/14651858.CD007868.pub2


**Table**

**TABLE 1. Recommended dietary fluoride supplement* schedule**

<table>
<thead>
<tr>
<th>Age</th>
<th>Fluoride concentration in community drinking water(^1)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt;0.3 ppm</td>
</tr>
<tr>
<td>0–6 months</td>
<td>None</td>
</tr>
<tr>
<td>6 months–3 years</td>
<td>0.25 mg/day</td>
</tr>
<tr>
<td>3–6 years</td>
<td>0.50 mg/day</td>
</tr>
<tr>
<td>6–16 years</td>
<td>1.0 mg/day</td>
</tr>
</tbody>
</table>

* Sodium fluoride (2.2 mg sodium fluoride contains 1 mg fluoride ion).

\(^1\) 1.0 parts per million (ppm) = 1 mg/L.

**Sources:**


Adapted from CDC: “Recommendations for Using Fluoride to Prevent and Control Dental Caries in the United States,” 2001
Abstract

**Objective:** The purpose of this literature review is to assess risk factors for dental fluorosis in U.S. children and to determine whether everything possible is being done to minimize the risk while keeping fluoride’s caries-preventative properties to a maximum.

**Methods:** The literature review analyzes articles found by using several search engines such as PubMed, the Cochrane Library, and Science Citation Index.

**Results:** There are many sources of fluoride exposure. Although all of them can be considered risk factors to different degrees, it is the combined exposure during tooth development that needs to be adjusted.

**Conclusion:** United States is taking steps to lower fluoride exposure in children by proposing to lower the recommended amount of fluoride in water to 0.7mg/L. There are other options available as well. Time alone will tell whether fluoride level adjustment in the water will significantly lower fluorosis prevalence.