Current Fluoride Modalities for Reduction of Dental Caries

A Peer-Reviewed Publication
Written by Heidi Emmerling Muñoz, RDH, PhD, FAADH and Ellen Standley, RDH, BS, MA

Abstract
The dental profession has long regarded fluoride as a primary element in the prevention of dental caries. Topical and systemic fluorides are regularly incorporated within the community, dental office, and home avenues. Despite the fact there are other preventive modalities, fluoride remains a well-established, evidence-based therapeutic intervention. This article will review the early history; mechanism of action; delivery methods for fluoride in private practice, home, and community; and the clinician’s role in optimizing best practices and safe use of fluoride.

Educational Objectives
At the completion of this article, the health care provider shall be able to:
1. Discuss the early studies in the United States on fluoride and its relationship to caries.
2. Explain the mechanisms of the preventive actions of fluoride.
3. Describe the basic delivery modalities of systemic and topical fluorides including pertinent information related to their use.
4. Discuss the clinician’s role in optimizing best practices and safe use of fluorides.

Author Profiles
Heidi Emmerling Muñoz, RDH, PhD, FAADH is a professor of English at Cosumnes River College. Prior to her current role, Dr. Muñoz served as interim director and professor of dental hygiene at Sacramento City College and was a CODA site consultant. Additionally, she is owner of Writing Cures (www.writingcures.com), a writing and editing service, co-author of The Purple Guide: Paper Personas, and creator of the Career Development Center for Friends of Hu-Friedy. She is a frequent contributor to RDH Magazine and has written articles and columns for a variety of publications. Dr. Muñoz can be reached at Munozh@crc.losrios.edu

Ellen Standley, RDH, BS, MA, is a recently retired professor of dental hygiene at Sacramento City College where she taught for over 30 years. She is a member of the American Dental Hygienists’ Association, the California Dental Hygiene Educators’ Association and the American Academy of Dental Hygiene. Ms. Standley is a past president of the California Dental Hygienists’ Association and currently serves on the Journal Advisory Board of the Journal of the California Dental Hygienists’ Association. She can be reached at ellenrdh@winfirst.com

Author Disclosure
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Abstract
The dental profession has long regarded fluoride as a primary element in the prevention of dental caries. Topical and systemic fluorides are regularly incorporated within the community, dental office, and home avenues. Despite the fact there are other preventive modalities, fluoride remains a well-established, evidence-based therapeutic intervention. This article will review the early history; mechanism of action; delivery methods for fluoride in private practice, home, and community; and the clinician’s role in optimizing best practices and safe use of fluoride.

Early History
In 1901, Frederick McKay opened his first dental practice in Colorado where he discovered residents had severe brown stain and mottling that was resistant to decay. McKay researched this aspect of staining, despite the lack of concern by citizens and lack of interest by local dentists. Some early research, funded by a $21 grant posited that excess pork consumption, drinking milk from local cows or even exposure to radium was the cause of “Colorado Brown Stain.”

G. V. Black, credited with being one of the nation’s most eminent dental researchers, came to Colorado to collaborate with McKay in investigating the prevalence of the Colorado Brown Stain.

For six years, Black and McKay researched fluoride. First they showed that mottled enamel occurred during tooth development in childhood. Next, they found that the teeth that had the stain had almost no dental decay. Still not knowing the cause, some local residents suggested researching the water. McKay thought this had possibilities while Black was not convinced. In 1923, McKay went to Idaho because he learned that Idaho children also had brown stain, and discovered the stain did not occur until a new water line was installed from a local spring. McKay still did not know what was in this spring and he prudently advised they change water supplies. Several years later, there was no longer mottling or brown stain. Next, McKay traveled to Bauxite, Arkansas, an aluminum company town (ALCOA), because there had been reports of brown stain there too. H. V. Churchill, the chief chemist of ALCOA, hoping to dispore the fear of the dangers of aluminum, decided to conduct his own test of the water. Churchill discovered there were high levels of fluoride in the water and subsequently wrote a letter to McKay in 1931 reporting his findings. McKay collected water samples which confirmed Churchill’s assertion that fluoride, not aluminum, was causing the stain.

In the 1930s, the United States Public Health Service (USPHS) started investigating fluoride and its relationship to tooth mottling. The head of the Dental Hygiene Unit of the National Institute of Health (NIH) was H. Trendley Dean, who researched the level of fluoride and the degree of fluorosis. Dean devised the fluorosis index and was credited with finding that 1 part per million (ppm) of fluoride in the drinking water was considered the ideal level for prevention of decay along with minimal fluorosis.

The Health and Human Services (HHS) and the Environmental Protection Agency (EPA) have lowered this level to 0.7 ppm in recent years to further minimize the risk of fluorosis.

In 1945 the USPHS decided to implement a research project by adding fluoride to the water supply in Grand Rapids, Michigan. Results were compared to a control city with no added fluoride. Thus, Grand Rapids was the first city to have water fluoridation and served as an early model for epidemiological fluoride research.

After 11 years, the outcomes revealed that the children of Grand Rapids born after the water fluoridation had a 60% reduction in caries. This finding was groundbreaking because it proved that dental decay could be prevented. Thanks to the pioneers McKay, Black, Churchill, and Dean, with addition of fluoride to the water and subsequently to dentifrices, rinses, and other dental products, consumers experience significantly less decay.

Basics of Fluoride Delivery and Application
Fluoride is available in many different products and modalities of delivery. Three basic categories of delivery are currently used:

- Systemic: ingested with water supplies or dietary supplementation or food
- Topical: home/self application of dentifrices, rinses, or gels.
- Topical: professional application of higher concentration products in the dental office

Fluoride delivery methods are either systemic (ingestion) or topical (surfaces of the teeth). It should be noted that systemic fluoride also provides some topical benefits when the ingested fluoride is circulated in the blood and emerges in very low levels in saliva. In early days it was thought that fluorides benefitted mainly children; it is now acknowledged that benefits extend to adults as well as children.

The frequent low level concentration of topical delivery is the main source of the decay reduction benefits.

Mechanism of Action
Fluoride reduces decay via three modes:
1. Incorporation of fluoride into the enamel during tooth development. This results in the formation of fluorohydroxyapatite, which is more resistant to the acid attacks of the decay process and is a systemic benefit.
2. Remineralization/demineralization mechanism. A major topical benefit. Fluoride enhances remineralization by combining with the tooth and making the coronal enamel

3. Staining of the enamel. Despite the lack of concern by citizens and lack of interest by local dentists, some early research, funded by a $21 grant posited that excess pork consumption, drinking milk from local cows or even exposure to radium was the cause of “Colorado Brown Stain.”

4. The frequent low level concentration of topical delivery is the main source of the decay reduction benefits.
and root surfaces more resistant to decay. The more resistant remineralized enamel in turn serves as a deterrent to the acids, which act to remove minerals from the tooth surface (demineralization).3,6-10

3. Glycolysis inhibition in caries bacteria. Another topical benefit, fluoride interferes with the bacterial metabolism of carbohydrates and reduces acid production, which in turn reduces decay.3,6-10

**Delivery Methods and Benefits**

**Systemic**

**Water Fluoridation:** Early Grand Rapids studies showed a 60% reduction in decay with water fluoridation. This impressive reduction made for compelling reasons for water fluoridation throughout the country. In 2010, 73.9% of the U.S. population on community water systems received fluoridated water.12 Initially, fluoridated water was the only source of fluoride. Through the years dentifrice and other vehicles for fluoride delivery came on the market. The increased availability of fluoride from a variety of sources produces a dilution of the benefits from any single source. Therefore, decay reduction from water fluoridation alone shows a more modest caries reduction of 20-40%.3 Additionally, the diffusion, or halo effect, contributes to this lower number by the fact that residents of nonfluoridated communities may consume food and beverages manufactured in fluoridated areas; individuals may also work in a fluoridated community but still reside in a nonfluoridated community, thereby benefitting from water fluoridation while at work.3,7 Despite other sources of prevention, fluoridation continues to be a safe and effective measure for caries reduction for all members of the community.3,7 In 1999 the Centers for Disease Control and Prevention named water fluoridation as one of the top ten public health measures of the 20th century.3,4,7

**Supplements:** Besides consuming water, another mechanism for systemic fluoride is through dietary supplements. Supplements are prescribed by physicians or dentists for children when the community does not have optimum water fluoridation. Sodium fluoride supplements are available in drops for infants or tablets/lozenges for young children.3,6,9,11 In 1994 the prescription age/dose schedule for fluoride tablets or drops was lowered to minimize the risk of fluorosis and to account for other available sources such as dentifrices, infant formulas, and foods made with fluoridated water (diffusion and halo effect).3,6 Recommendations for supplements are more conservative than in the past. Fluoride supplements are particularly recommended for children who are at high risk for caries and who do not regularly brush with a fluoride dentifrice.3,11,13-14 The American Dental Association chairsied guide for fluoride supplements states that children who have low caries risk should not receive supplements.3,15 Furthermore, the practitioner should carefully evaluate all sources of fluoride and conduct a risk assessment before prescribing supplements. The 2010 Dosage Schedule can be found on the American Dental Association website at http://ebd.ada.org/contentdocs/6327_Fluoride_Chairsied_Tool.pdf.16 When supplements are indicated, they should not be initiated until six months of age.7,9,14-16 Further, to maximize the effect, tablets or lozenges should be chewed or sucked on for at least one to two minutes before being swallowed.5,10,13,16

There has been much discussion on the efficacy of prenatal fluoride. While not contraindicated at this time, the American Academy of Pediatric Dentistry does not support the use of prenatal fluoride supplements because research has indicated that there is no measurable benefit compared to postnatal fluoride alone.6,14-15,17-20

**Salt and Milk:** Regions that do not have a fluoridated water supply, including places in South America, Latin America, the Caribbean, and Western Europe, add fluoride to their salt. It is a convenient alternative and is met with good public acceptance.5,19,20 Fluoride salt is not used in the United States or Canada, since water fluoridation is fairly common in these regions.19-21 Although not as popular as fluoride salt, the addition of fluoride to milk has been used in a few international communities. However, the evidence supporting fluoride milk to reduce tooth decay is weak.3,19,20

**Topical**

Topical fluorides are considered the main source of postnatal benefits and include both home and professional/office applications.3,6,10,14,19,23 Mechanisms of action and caries reduction benefits for topical fluorides have been the subject of much discussion and ongoing research.3,6-11,14 Recommendations for the use of topical fluorides for children and adults vary with respect to frequency of use (daily, monthly, or yearly), concentration (lower or higher), and level of risk or susceptibility to caries.6,11,13-14,16,20

**Home Topical Applications**

**Dentifrices:** One major source of topical fluoride is dentifrice. While systemic water fluoridation has impressive benefits, many authorities attribute the use of fluoride dentifrice as the main vehicle for the global reduction in caries because of its ability to reach a wider population.20 Between 1960-1964, fluoride dentifrices were being marketed and recognized as viable therapeutic mechanisms for reduction of decay.7 Dentifrices can contain either sodium fluoride (NaF), stannous fluoride (SnF), or sodium monofluorophosphate (MFP).7,8 The amount of fluoride in the dentifrice is important. Cochrane reviewers found that a minimum of 1,000 ppm of fluoride should be present in dentifrices to be effective in preventing caries in children.21 For the optimal caries reduction benefit, over-the-counter (OTC) fluoride dentifrice levels need to be between 1000-1500 ppm.13,20 Twice-a-day brushing is recommended for over-the-counter fluoride dentifrices.6,11,13,16,19,21 To maximize the effect, individuals should avoid rinsing after brushing so that more fluoride is retained in the saliva.6,20,25

Recommendations for the use of daily over-the-counter fluoride dentifrices are targeted for quantity of dentifrice according to age and level of caries risk. Fluoridated dentifrices should be used only by adults and children over two; young children under two with low caries risk should use dentifrice without fluoride or a toothbrush moistened with water.5,11,13,16,19 The American Dental Association and the American Academy of Pediatric Dentistry recommend consulting with a dentist or physician before using a fluoride dentifrice.
on children under age two. Following advice by a dentist, parents can place a minuscule amount of fluoride dentifrice on a brush for children under two. The amount has been described as: smear, film, rice, small pea, tiny touch. For all slightly older children (aged 3-6 years), the recommendation is to use fluoride dentifrice with a pea or small pea size. To minimize the risk of fluoroosis, experts caution that children must not swallow fluoride dentifrice during or after brushing. Additional safety precautions for the 3- to 6-year-olds include keeping the dentifrice container out of the child’s reach and having adult supervision or assistance while brushing.

Prescription strength fluoride comes in dentifrice and gel formulas for home use. These products are used by the high caries risk patient 6 years of age and older. NaF and acidulated phosphate fluoride (APF) prescription strength gels contain levels up to 5,000 ppm. An OTC SnF gel that is sometimes recommended by dental professionals is 1,000 ppm.

**Mouth rinses:** In addition to dentifrices and gels, topical fluorides are marketed in mouth rinses with NaF, SnF, or APF. Daily OTC sodium-based mouth rinses are 0.02% (NaF), .044% (APF) or, 0.05% (NaF), which is the most common. Another daily rinse is .63% SnF, which is indicated for dentinal sensitivity and gingival inflammation as well as caries. Available by prescription only for weekly use is 0.2% NaF, which is used for high-risk individuals or for public health school rinse programs. Most sources recognize mouth rinses are not appropriate for children under age 6 or any individual who has difficulty expectorating. For optimum efficacy, mouthwashes should be used for the prescribed amount of time indicated on the bottle, which is usually one minute.

See Table 1 for summary of home-use topical fluoride.

<table>
<thead>
<tr>
<th>Formula</th>
<th>Concentration</th>
<th>Prescription</th>
<th>OTC</th>
</tr>
</thead>
<tbody>
<tr>
<td>NaF</td>
<td>.22%(1,000 ppm)</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>SnF</td>
<td>.4%</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>NaF MFP</td>
<td>.22%</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Gel</td>
<td></td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Up to 5,000</td>
<td>NaF</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>1,000</td>
<td>SnF</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Mouth rinse</td>
<td>230 NaF</td>
<td>0.05% (most common)</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>NaF</td>
<td>0.02%</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>NaF Plus APF</td>
<td>0.04%</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>920 NaF</td>
<td>0.2%</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>200 NaF</td>
<td>0.044%</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>SnF</td>
<td>0.63%</td>
<td>Yes</td>
</tr>
</tbody>
</table>
of the newer materials are not as sensitive to the effects of the APF.\textsuperscript{19} Evidence reveals that the NaF and AFP gels are similar in efficacy.\textsuperscript{27} The foam forms of APF and NaF require a much smaller amount to fill the trays and thereby reduce the risk of ingestion.\textsuperscript{6,8-9} The recommended time for professional fluoride tray applications is four minutes to obtain maximum benefits.\textsuperscript{6-9,13,19,27} Patients should be advised not to rinse, eat, or drink for 30 minutes following high concentration fluoride applications to maximize effectiveness.\textsuperscript{6-9,13,19}

Another application that is rarely used, with its high concentration of 20,000-25,000 ppm, is an 8% SnF solution. Since it is SnF, it has a less pleasant taste, and there is a potential problem for staining as well as gingival sloughing. Instability is another disadvantage of this formulation.\textsuperscript{8}

At one time, a two-part fluoride rinse consisting of 0.31% APF and 1.64% SnF was popular. At 1,500-3,000, the ppm was lower than gels and foams. However, the lack of clinical evidence no longer warrants its use.\textsuperscript{9} See Table 2 for a summary of professional topical solutions.

**The Clinician’s Role in Optimizing Safe Use of Fluorides**

Dental hygienists should keep informed on the current use of fluoride modalities, best practices, and safe strategies. Additionally, it is important to inform the patients how to maximize efficacy and minimize potential risks.

**Caries Risk Assessment:** Caries risk assessment is evidence-based and considered the current best practice when clinicians implement and recommend caries prevention strategies.\textsuperscript{27-28} Each patient is evaluated with consideration for clinical exam, history of recent caries, nutritional and oral hygiene practices, and many other factors. Several risk assessment forms and articles are available and can be downloaded.\textsuperscript{14-16,27-28}

**Acute and Chronic Toxicity:** Acute fluoride toxicity results from short-term ingestion of higher concentrations of fluoride. Symptoms can range from mild nausea to more severe GI symptoms and, in extremely rare cases, death.\textsuperscript{7,9} The severity of symptoms is affected by the amount of fluoride ingested, the patient’s weight, and the patient’s health status.\textsuperscript{7,9} Mild nausea is the most common form of fluoride toxicity and is experienced when patients swallow too much topical fluoride. The fluoride reacts with the stomach acid, forming hydrogen fluoride and produces symptoms of nausea, cramps, and vomiting, usually within 30 minutes of swallowing.\textsuperscript{7,9,19}

Chronic fluoride toxicity results from long-term ingestion of lower concentrations of fluoride, and is most commonly experienced as dental fluorosis.\textsuperscript{3,6-7,9,13,17,23} Fluorosis ranges from mild chalky white spots to severe brown mottling.\textsuperscript{3,6} Fluorosis develops when low doses of fluoride are regularly and inadvertently ingested during enamel development.\textsuperscript{3,6} Although fluorosis is seen when the fluoride concentration in the water is greater than optimal, some cases of fluorosis result from long-term swallowing of OTC dentifrices, and/or the use of supplements and fluoridated infant formula in addition to consuming water that is already optimally fluoridated.\textsuperscript{3,6,9,13,17,23}

**Safe Tray Applications:** To avoid the potential of acute toxicity symptoms, common sense dictates that clinicians follow best practices when administering tray applications of fluoride. These include:\textsuperscript{7,9,19}

1. Load a minimal amount of product for tray applications. To minimize the risk of ingestion, load 2 ml per tray for small children and no more than 5 ml per tray for adults. Have the patient sit upright.
2. Apply adequate suctioning throughout the procedure.
3. Directly supervise the patient, especially young children, during the administration of fluoride. Children are at a greater risk of fluoride toxicity since they do not weigh as much as adults and also tend to swallow topical fluoride. Thus, careful supervision of child during fluoride treatments is essential.
4. Instruct the patient to expectorate and not to swallow the product.
5. Advise the patients who have a tendency to swallow product that they can ingest milk or an antacid product (calcium carbonate) to bind with the fluoride, reducing the risk of nausea.

**Reminders for Patients:** It is important that clinicians advise patients of safety precautions for home use of fluoride products. Safety messages to convey include:\textsuperscript{7,9,13,14,19,33}

<table>
<thead>
<tr>
<th>Table 2. Professional use topical fluoride</th>
<th>6,7,13,27</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type</strong></td>
<td><strong>PPM</strong></td>
</tr>
<tr>
<td>----------</td>
<td>---------</td>
</tr>
<tr>
<td>Varnish</td>
<td>22,600</td>
</tr>
<tr>
<td></td>
<td>1,000</td>
</tr>
<tr>
<td>Gels</td>
<td>12,300-</td>
</tr>
<tr>
<td></td>
<td>12,500</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Solution</td>
<td>9000</td>
</tr>
<tr>
<td>Solution</td>
<td>20,000-</td>
</tr>
<tr>
<td></td>
<td>25,000</td>
</tr>
</tbody>
</table>
All fluoride products, including OTC dentifrices and rinses, must be stored out of the reach of small children. Further precautions dictate that prescription fluoride should be stored in a secure area.

Remind patients that the proper amount of dentifrice for a small child to use is the size of a small pea.

No mouth rinses should be used by children under the age of six or by individuals who have limited ability to expectorate.

Mouthrinses and dentifrices should not be swallowed. Therefore, parental supervision of young children is essential.

Before supplements and/or fluoridated infant formula are used, check the fluoride content of the local water supply. If the fluoride concentration is at the optimal level, supplements and fluoride-enriched formula should not be used.

When daily supplements are taken, parents should be advised that if a dose is missed, simply resume the next day with the normal dose. Do not double dose.

Remind parents that if fluoride is ingested and nausea is experienced, they should take proper measures by having the child consume milk or an antacid product to bind with the fluoride. If accidental ingestion of a larger amount of fluoride product occurs, the National Hotline for Poison Emergencies is available for 24 hour advice. (1-800-222-1222).

Conclusion

Because practitioners and consumers have enjoyed the benefits of fluoride for a number of years, fluoride is often taken for granted as one of the most effective tools for caries prevention. Whether in the water supply or in topical agents such as daily dentifrice, fluoride continues to be relied on as a preventive measure. Despite its long-standing history and use, clinicians should have basic knowledge of the products and of the safe use of these products. Communication to the patient is an important adjunct to maximize the benefits and minimize the risks. Timely implementation of caries risk assessments and of appropriate strategies for each patient’s level of risk are essential components of evidence-based practice. From its early history to the present time, fluoride remains an effective, evidence-based modality for caries prevention throughout the lifespan.

References

25. Duckworth RM, Maguire A, Omid N, Steen IN, McCracken GI,


1. What is the revised ppm fluoride that is recommended currently for community water fluoridation?
   a. .5 ppm
   b. .7 ppm
   c. 1 ppm
   d. 2 ppm

2. The extension of food and beverage products manufactured with fluoridated water and distributed to areas without fluoridation is known as:
   a. diffusion or halo effect
   b. hydrolysis benefit
   c. placebo effect
   d. indirect benefit

3. Which of the following is true about fluoride supplements?
   a. all children should have fluoride supplements
   b. fluoride supplements should be initiated during the first two years
   c. children with low caries risk should not receive fluoride supplements
   d. adolescents can benefit from fluoride supplements

4. Which of the following topical fluorides has the lowest risk for swallowing?
   a. dentifrices
   b. mouthrinses
   c. gels
   d. varnishes

5. What is the topical fluoride application of choice for patients with multiple porcelain or composite restorations?
   a. sodium fluoride
   b. acidulated phosphate fluoride
   c. stannous fluoride
   d. calcium fluoride

6. Fluoride mouthrinses are not recommended for:
   a. children under six
   b. children under ten
   c. patients who have difficulty expectorating
   d. a and c

7. Brushing recommendations for parents with children under 2 years old are:
   a. use no toothpaste or a small wipe of toothpaste with no fluoride
   b. use no fluoride toothpaste unless advised by a dentist
   c. brush the child’s teeth twice daily with a fluoride toothpaste
   d. a and b

8. Professional fluoride applications are primarily indicated for:
   a. patients with higher caries risk
   b. all patients who do not use fluoridated water
   c. all children over 6 years old
   d. children with primary dentition

9. To maximize the benefits of fluoride dentifrice, patients are advised to:
   a. brush five times a day
   b. avoid rinsing after
   c. follow-up with a 10 second water rinse
   d. avoid food and beverages for three hours after

10. For maximum preventive benefits, office application of fluoride gels should be:
    a. one minute
    b. two minutes
    c. three minutes
    d. four minutes

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