Caries Process and Prevention Strategies: Intervention

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Conflict of Interest Disclosure Statement
• Mr. Faller is a retired employee of P&G.

Introduction
This is part 9 of a 10-part series entitled Caries Process and Prevention Strategies. This course introduces the dental professional to the important role of fluoride in the prevention and control of dental caries. Systemic and topical forms of fluoride delivery are discussed as options for the majority of patients, and professional forms of fluoride delivery are discussed as sometimes-necessary measures for high-risk patients with severe caries.
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Overview

This course introduces the dental professional to the important role of fluoride in the prevention and control of dental caries. Systemic and topical forms of fluoride delivery are discussed as options for the majority of patients, and professional forms of fluoride delivery are discussed as sometimes necessary measures for high-risk patients with severe caries.

Clinical Significance Snapshots

How can I find out if my patients are getting fluoridated water?
Contact the local water supplier or State Health Department. Almost 70% of the US population receives water in which the concentration of fluoride has been adjusted to optimal levels. This percentage cannot increase much more, as it is challenging to adjust the fluoride content of wells and other individual water sources. With the increased consumption of bottled water, not all people living in an area of water fluoridation may be receiving the optimal amount of fluoride.

Are all fluoride toothpastes the same?
Not necessarily. Every manufacturer uses its own proprietary formulations. Fluoride compounds are very reactive, and without good chemistry at the formulation stage, some or all of the fluoride can become bound to other ingredients in the paste and not be available for binding to the surfaces of teeth.

Commonly used fluoride sources include Stannous fluoride, Sodium fluoride, and Sodium monofluorophosphate. A toothpaste brand carrying the Seal of Acceptance of the American Dental Association will have demonstrated in various studies that the fluoride is both safe and effective.

Learning Objectives

Upon completion of this course, the dental professional should be able to:

• Be familiar with the history of fluoride in caries control.
• Discuss how fluoride is processed by the body.
• Describe how fluoride concentration varies in different parts of the tooth.
• Identify the multiple ways in which fluoride provides protection from caries.
• Explain the dental health consequences of too much fluoride exposure.
• Discuss the primary methods of systemic and topical fluoride delivery.
• Understand when professional forms of fluoride delivery may be necessary.

Glossary

biofilm – An aggregation of microorganisms in which cells adhere to each other forming small communities that are held together by an extracellular polymeric matrix. Different communities are co-dependent on each other, and the whole biofilm forms a defensive mechanism requiring much higher concentrations of antimicrobials to control its growth. Dental plaque is a classic biofilm.

demineralization – The chemical process by which minerals (mainly Calcium) are removed from the dental hard tissues – enamel, dentin, and cementum. The chemical process occurs through dissolution by acids or by chelation, and the rate of demineralization will vary due to the degree of supersaturation of the immediate environment of the tooth and the presence of
fluoride. In optimal circumstances, the minerals may be replaced through the process of remineralization.

**dental fluorosis** – An abnormal condition caused by the excessive intake of fluorine, such as from fluoridated drinking water, during the period in which tooth buds are developing (amelogenesis), and is characterized in the developed tooth chiefly by mottling of the enamel. This condition can range from white flecks in the enamel (mild fluorosis) up to brown, stained and pitted enamel (severe).

**enzyme** – Protein that catalyzes, or facilitates, biochemical reactions.

**fluoride** – The anion of the halogen fluorine (F⁻). Compounds containing the fluoride anion are collectively called fluorides. Fluoride compounds very commonly occur, from simple fluoride tooth pastes to PTFE (Teflon).

**fluoride dentifrice** – A toothpaste that has been formulated to deliver clinically proven amounts of fluoride into the oral cavity, and to bind to tooth surfaces creating fluorapatite and Calcium fluoride, both of which protect the tooth from the acids produced by cariogenic bacteria.

**fluoride supplements** – The diet of children can be supplemented with sodium fluoride, similar to vitamin supplementation, in areas where water fluoridation, or availability of fluoride by other means, such as milk or salt, may not be available.

**fluorapatite** – A crystal structure in tooth mineral (Ca₁₀(PO₄)₆F₂) resulting from the replacement of hydroxyl ions (OH⁻) in the hydroxyapatite structure with fluoride ions (F⁻). Fluorapatite (also commonly referred to as fluroapatite, fluorhydroxyapatite or fluorohydroxyapatite) is stronger and more acid resistant than hydroxyapatite.

**hydroxyapatite** – Crystals of calcium phosphate - Ca₁₀(PO₄)₆OH₂- that form the mineral structure of teeth and bone. Enamel comprises approximately 98% hydroxyapatite. Much of the hydroxyapatite in enamel, however, is a calcium-deficient carbonated hydroxyapatite, the crystals of which are readily dissolved by acids. The addition of fluoride creates fluorapatite, which is less soluble and more acid-resistant.

**hypominalization** – Relating to or characterized by a deficiency of minerals.

**milk fluoridation** – Milk provides an ideal vehicle to deliver the correct amount of fluoride to children. However, well-controlled studies have not yet been conducted to confirm the anticaries benefits of this approach, and this is necessary before this method can be recommended for implementation in the United States.

**mottled enamel** – A chronic endemic form of hypoplasia (incomplete development) of the dental enamel caused by excessive intake of fluoride by a child during key stages of tooth formation. It is characterized by defective calcification that results in a chalky appearance to the enamel, which gradually undergoes brown discoloration.

**remineralization** – The chemical process by which minerals (mainly calcium) are replaced into the substance of the dental hard tissues - enamel, dentin and cementum. The process requires an ideal environment that includes supersaturation with calcium and phosphate ions, the presence of fluoride, and adequate buffering.

**water fluoridation** – The addition or removal of fluoride from domestic water supplies to achieve the optimal concentration of fluoride. The optimal concentration varies due to ambient temperature of the climate and thus water intake. Hexafluorosilicic acid (H₂SiF₆) and its salt sodium hexafluorosilicate (Na₂SiF₆) are the more commonly used additives, especially in the United States.

**Introduction**

It can be argued that the role of fluoride in caries prevention is one of the biggest success stories in the field of public health. In fact, in 1999, the U.S. Center for Disease Control (CDC) declared water fluoridation to be “one of the 10 most important public health measures of the 20th century.” However, just as it is well-documented that fluoride has beneficial effects on dentition because of its ability to reduce...
caries, it is also well known that an excessive amount of fluoride can also have detrimental effects on teeth, namely in the form of dental fluorosis. Because of that, there are many in the dental profession who advocate the use of fluoride, but some who are adamantly against it. What follows is a summary of what is known about the effects of fluoride on developing and erupted teeth, as well as information on the current forms of fluoride delivery. The goal is to get dental health professionals on the road to making informed decisions about fluoride use that maximize the anticaries benefits, while minimizing the risk of dental fluorosis.

Brief History Of Fluoride In Caries Control

The credit for the identification of fluoride as an effective means of caries prevention can be largely accredited to two American dentists, Frederick McKay and H. Trendley Dean. Interestingly, this knowledge came about by first noting the detrimental effect of excessive fluoride on tooth enamel. This is a condition called dental fluorosis, in which teeth become speckled with white flecks. In more severe cases of excessive fluoride ingestion, teeth can become mottled with brown stains and chunks of surface enamel might easily break off, though these types of effects are limited to the most severe cases and are not generally seen in the United States.

As a practicing dentist in Colorado Springs, Colorado, in 1901, McKay noticed many of his patients had what was locally called “Colorado brown stain”. He moved out of the area, but returned in 1908 to study the phenomenon in more detail, and found that as many as 90% of children were affected. In addition, after conferring with other dentists worldwide, he found similar occurrences of mottled or brown enamel in other towns in the United States, England, and Italy. Because the phenomenon was isolated to specific geographical areas, McKay thought that the water supply might be an important factor. He put this theory to the test in Oakley, Idaho, where mottled enamel was common, by having a pipeline with an alternative water source pumped into the town. After 10 years of the new water supply, new cases of “brown stain” had disappeared. To add another piece to the puzzle, analysis of water in another American town plagued by mottled enamel, Bauxite, Arkansas, uncovered an unexpectedly high level of fluoride—and these high levels were confirmed in the water supply of other towns with rampant dental fluorosis.

The discovery of high concentrations of fluoride was a concern because it was known that high doses of the mineral could be poisonous. This is when H. Trendley Dean, who worked with the US Public Health service, came on the scene. He took up the investigation, mapping areas where mottled enamel was present and relating the severity of mottled enamel to fluoride concentrations, noting that a certain range of fluoride concentrations in drinking water that was not very high or very low was linked with a reduced caries risk.

In a publication in 1942, Dean published his findings of his landmark “21 city study” (actually a series of studies) where he examined the association between the fluoride levels in drinking water and caries levels in children, and developed the first classification system for recording the severity of mottled enamel, using the terms questionable, very mild, mild, moderate, and severe. These findings from the first half of the 1900s led to a greater understanding of fluoride’s effects on enamel development, how dental fluorosis develops, and advances in the delivery of beneficial amounts of fluoride to reduce caries.

Fluoride In The Body And Its Role In Enamel Development

Following the ingestion of fluoride from a water, food, or supplement source, 86% to 97% of the element is absorbed in the stomach and small
Fluoride In Caries Protection And Fluorosis

Reduced Demineralization And Enhanced Remineralization
This is the main mechanism by which fluoride exerts its anticaries benefits. It has been established that hydroxyapatite starts to dissolve when pH drops below 5.5, and fluorapatite starts to dissolve when the pH drops below 4.5. If biofilm pH is lower than 5.5 but higher than about 4.5 and fluoride is available in low concentrations, fluorapatite forms on the surface layers of enamel even if hydroxyapatite dissolves in the subsurface enamel. The overall effect is reduced dental demineralization thanks to the protective outer layer of fluorapatite. When oral pH normalizes after an acid attack and rises again above 5.5, fluoride enhances enamel–dentin remineralization. If fluoride is no longer available, the oral environment begins to favor demineralization if the pH falls below 5.5.1

Antimicrobial Qualities
Fluoride ions inhibit the bacterial enzyme enolase, which interferes with the production of phosphoenolpyruvate (PEP). PEP is a bacterial source of energy and a molecule that is necessary for the uptake of sugar, which provides bacterial nutrition. A dental biofilm that contains just 1 ppm to 5 ppm of fluoride (an amount that is reached by using fluoridated toothpaste) is found to inhibit the adhesion, growth, metabolism, and multiplication of caries-linked oral streptococci. The presence of higher concentrations of fluoride—10 ppm to 100 ppm, which can be obtained in prescription fluoride preparations—has also been found to inhibit acid production by most plaque bacteria.10

Fluorosis
An abnormally high concentration of fluoride leads to hypomineralization of the tooth’s enamel and increased porosity that is reflected in the opacity of enamel as chalky white lines or stains. In general, teeth with more severe dental fluorosis have significantly higher levels of fluoride in enamel than those with

Fluoride Concentration In Teeth
After fluoride is ingested, it is distributed from the plasma to all tissues and organs of the body, and gradually becomes incorporated into the crystal lattice structure of teeth in the form of fluorapatite. In teeth, the fluoride concentration is very high on surface enamel, but falls steeply within the first 100 µm. Then fluoride concentration remains constant up to the enamel–dentin junction. Fluoride concentration once again increases inside the dentin, increasing deeper into the tooth, with fluoride steadily accumulating over a lifetime at the dentin–pulp surface. It should be noted that there is no homeostatic mechanism that maintains fluoride concentration in the body. Therefore, regular exposure is required to maintain fluoride concentration in enamel, saliva, and in biofilm on dental surfaces.1

Video 2. Enamel Maturation - How is fluoride incorporated into the inorganic phase of enamel, pre- and post-eruptive?
Click on image to view video online.
less severe forms of dental fluorosis. Also, the extent and degree of hypomineralization increases with increased fluoride exposure during development. In cases of severe hypomineralization, porous enamel appears brown and it can be very fragile, with surface damage occurring quite easily during chewing, attrition, and abrasion.¹

### Systemic Fluoride Delivery

A primary method of fluoride delivery is systemic, being artificially provided in water, milk, salt, or supplements, which must be ingested to be able to have any effect on teeth. In all of these applications, the primary action of fluoride in promoting remineralization and reducing demineralization is due to the presence of fluoride in a beneficial amount and at the right time. What follows is a brief discussion of the main forms of systemic fluoride delivery employed by dental professionals worldwide today:

#### Water Fluoridation

Water fluoridation is the primary systemic method of fluoride delivery to the American population. Fluoride occurs naturally in water supplies, usually at very low concentrations of 0.1 ppm. Community water studies have uncovered a few key findings:
- Overall, there is a 50% reduction in dental caries rates among children with 1 ppm fluoride in the community drinking water.¹¹
- However, this caries protection occurs only with consistent fluoride exposure. This is evident in studies that found that children who move to a nonfluoridated water community experience an increase in caries rates. In addition, adults also benefit from fluoride, with reduced coronal and root caries rates among those residing in fluoridated water communities.¹

In the United States, it is estimated that more than 204 million people (approximately 75% of the population) are served by fluoridated water supply systems. This is a relatively inexpensive endeavor: The annual cost of fluoridating the drinking water for a community larger than 20,000 people averages 50 cents per person. Just $1 invested in this preventive measure yields approximately $38 savings in dental treatment costs. The CDC monitors the progress of the country, as well as each individual state, toward meeting the *Healthy People 2020* objective on community water fluoridation – that by the year 2020, 79.6% of people on community water systems will receive water that has to optimal level of fluoride recommended for preventing tooth decay.

#### Salt Fluoridation

This is a method of fluoride delivery used primarily in Europe, as well as Costa Rica, Columbia, and Jamaica. A landmark Swiss study found that fluoridating table salt reduced children’s caries levels by 50% over a 10-year period.¹² There are concerns about excessive fluoride intake and the emergence of dental fluorosis, as well as concerns about increased salt intake.¹

#### Milk Fluoridation

Adding fluoride to liquid, powdered, and long-life milk has been implemented in Eastern Europe, China, the UK, and South America. It has the advantage over water fluoridation in that it can be targeted directly at certain segments of the population, and intake can be controlled.¹³ However, well-controlled studies have not yet been conducted, and this is necessary before this method can be recommended for implementation in the United States.¹

#### Fluoride Supplements

The Centers for Disease Control (CDC) currently recommend that oral fluoride supplements be used only in high-risk children residing in nonfluoridated areas. The recommended Supplemental Fluoride Dosage Schedule is as follows (Table 1).¹⁴

#### Topical Fluoride Delivery

Another main method of fluoride delivery is topical, in the form of toothpastes, gels, varnishes, paint-on formulations, and mouth rinses that come into contact with the surface of the tooth.

#### Fluoridated Dentifrice

Toothpaste has come a long way from its beginnings as pastes made from things like mashed eggshells and bones mixed with myrrh. The first clinically proven fluoride toothpaste was introduced in 1955 by Crest; it contained 0.4% stannous fluoride (SnF₂).
Each decade after that brought further advancements: In the 1960s, gel products hit the markets; in the 1970s antiplaque claims were introduced; tartar control products were first marketed in the 1980s; and the 1990s were marked by specialty products on the market, such as antigingivitis, whitening agents, and changes in the type of container used to deliver the dentifrice, such as pumps and dual chambers.¹

Today, over-the-counter dentifrice products in the United States contain between 850 ppm to 1150 ppm fluoride. Clinical trials indicate a dose-dependent relationship between fluoride concentration and caries prevention, with a 6% increase in efficacy and 8.6% reduction in caries for every 500 ppm fluoride increase.¹,¹⁵ To recap the caries-reducing benefits of fluoridated dentifrice: Research has documented that a regular low-dose source of fluoride is the most efficient means to prevent demineralization of teeth and to enhance remineralization. Fluoride becomes incorporated with the enamel apatite crystal, rendering the enamel more resistant to acid dissolution. Fluoride in saliva and plaque also promotes remineralization. And finally, fluoride also has a modest antimicrobial effect on plaque bacteria, with stannous fluoride being particularly effective against *Streptococcus mutans*.¹

The most common forms of fluoride used in U.S. dentifrices are sodium monofluorophosphate (SMFP), sodium fluoride (NaF), and stannous fluoride (SnF₂). Mixtures of NaF and SMFP, and amine fluoride (AmF) are also recognized as safe and effective forms of fluoride in over-the-counter therapeutic dentifrices in markets outside of the United States.

There are also prescription fluoridated gels that contain 5000 ppm fluoride that are intended for limited use in high caries risk patients. One 6-month study conducted in adults found that 57% of root caries lesions became hard in subjects using a 5000-ppm gel, compared to 29% for subjects who used a 1100-ppm toothpaste.¹⁶

### Recommendations For Fluoride Toothpaste

Clinical studies have found little association between the amount of toothpaste used and anticaries efficacy; instead, as explained above, fluoride concentration is the important determinant of anticaries efficacy. Therefore, using more toothpaste than is recommended (such as a pea-sized amount for children) does not provide more caries protection.¹

Brushing behavior is also important: Brushing twice a day is linked to a 20% to 30% lower likelihood of caries compared to brushing once or less daily.¹⁷ It should be noted that brushing frequency is linked to socioeconomic status, with children in poorer families brushing less, and this being one reason they experience more caries.¹⁸ While there

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<th>Age of child</th>
<th>Less than 0.3 ppm water fluoride concentration</th>
<th>0.3 ppm to 0.6 ppm water fluoride concentration</th>
<th>Greater than 0.6 ppm water fluoride concentration</th>
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<tr>
<td>Birth to 6 months</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
<td>6 months to 3 years</td>
<td>0.25 mg liquid drops</td>
<td>0</td>
<td>0</td>
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<tr>
<td>3 to 6 years</td>
<td>0.5 mg drops or tabs</td>
<td>0.25 mg</td>
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<tr>
<td>6 to 16 years</td>
<td>1 mg</td>
<td>0.5 mg</td>
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<th>Table 1. Recommended Supplemental Fluoride Dosage Schedule.</th>
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    | Age of child | Less than 0.3 ppm water fluoride concentration | 0.3 ppm to 0.6 ppm water fluoride concentration | Greater than 0.6 ppm water fluoride concentration |
    |--------------|---------------------------------------------|-----------------------------------------------|--------------------------------------------------|
    | Birth to 6 months | 0                                          | 0                                             | 0                                                |
    | 6 months to 3 years | 0.25 mg liquid drops                         | 0                                             | 0                                                |
    | 3 to 6 years | 0.5 mg drops or tabs                         | 0.25 mg                                       | 0                                                |
    | 6 to 16 years | 1 mg                                        | 0.5 mg                                        | 0                                                |
has been much debate about whether it is better to brush before or after meals, there is little scientific evidence to indicate the better option. However, data do show that brushing immediately before bed plays an important role in reducing plaque load in the oral environment during sleep, when salivary flow and buffering capacity are naturally reduced. Therefore, the recommendation to brush just before going to bed and at least one other time during the day before or after a mealtime is appropriate for most patients. Fluoridated toothpaste can also be used therapeutically by asking the patient to apply a dab of paste with a finger or brush directly to a cleaned active lesion immediately before going to bed. This also allows an increased concentration of fluoride in the vicinity of the lesion at a time of day when salivary output is naturally low.

Rinsing behavior is another determinant of anticaries efficacy. Studies show that people who use a cup to rinse with water after brushing (and so put more water in their mouths) have approximately 20% more caries than those who use the toothbrush or hand to collect water. This is because more fluoride is washed away when rinsing with a cup of water after brushing. In summary, dental professionals should recommend to their patients:
1. An accredited fluoride toothpaste.
2. A toothpaste with an appropriate fluoride concentration after assessing potential caries risk and overall fluoride exposure.
3. To brush twice daily; once at night and once more at another time during the day, preferably around a mealtime.
4. That children be given a minimum amount of toothpaste and be supervised when brushing.

Other Ingredients In Dentifrice
Toothpastes and gels also contain abrasives (such as hydrated silica) to clean teeth; binders (such as xanthan gum, carrageenan or carbopol) to prevent the separation of ingredients; coloring for visual appeal; humectants (such as glycerin or sorbitol) to retain moisture; buffers (such as phosphates) to maintain product stability; flavorings (such as peppermint and cinnamon); and surfactants (such as sodium lauryl sulfate) to produce a foaming action and reduce surface tension.

While the focus of this education course is caries, it is also useful to know of the other types of dentifrices to help address other individualized needs of the patient. These types provide plaque and gingivitis protection, tartar control, whitening, sensitivity protection, and protection from oral malodor. Many fluoride dentifrices today cover some combinations or all of these benefit areas in one dentifrice.

**Fluoride Mouth Rinses**
These are most commonly available as 0.02% NaF (100 ppm F) for twice a day rinsing, 0.05% NaF (227 ppm F) for daily rinsing and 0.2% NaF (909 ppm F) for weekly rinsing. These latter two higher concentration rinses may need a prescription even if they are intended for home use. Mouthwashes have also been formulated with acidulated phosphate fluoride, stannous fluoride, ammonium fluoride, and amine fluoride, although some of these come with precautions. For example, stannous fluoride rinses have been associated with discoloration of teeth and tooth restorations, and acidulate phosphate fluoride is contraindicated in people with porcelain or composite restorations because it can cause pitting or etching.

Many of the fluoride mouth washes on the market internationally also contain antimicrobial ingredients. These include chlorhexidine, cetylpyridinium chloride, triclosan, delmopinol, hexetidine, and Sanguinaria extract. Many of these have little to no caries-reducing effects or have not been studied for their anti-caries effects.

Typically, it is recommended that 10 ml of the mouth rinse solution be swirled around in the mouth for 1 minute. Clinical trials of both the daily and weekly regimen show an average caries reduction of 30%. The benefit of daily rinsing is marginally greater than weekly rinsing but not statistically significant. Overall, fluoride mouth rinses are considered beneficial from a public health perspective only if groups of people at high risk of caries are being targeted, since they are not cost-effective in a population with a low incidence of disease. While weekly rinsing public health programs have been used in the United States to target groups of people that are at high risk of caries, other countries...
stopped regular rinsing (either daily or weekly) with fluoridated mouthwashes in the 1980s.¹

**Professional Delivery Of Fluoride**

When a patient is at extremely high risk of caries, and appropriate dental care measures (such as good oral hygiene or the use of a fluoride toothpaste) are not working or are not being followed, professional forms of fluoride delivery may be considered.

**Professional Fluoride Gels Foams And Solutions**

These contain higher concentrations of fluoride than products sold over the counter for home use. They typically contain 5000 ppm to 12300 ppm and are applied only in the dental office. They are generally recommended for use twice yearly, although in severe cases, they may be applied more frequently. Significant reductions in dental caries—as much as 41%—have been seen when applied in this way.¹⁹ However, no benefit has been seen with the use of single applications or infrequent applications.

**Professional Fluoride Varnishes**

These contain a high level of fluoride (22600 ppm) and are applied only in a dentist’s office. Varnishes are used to deliver fluoride to specific sites or surfaces within the mouth and are typically applied every 3 months or 6 months. The correct application of a fluoride varnish has been linked with a 38% reduction in dental caries.²⁰ Varnishes are designed to harden on the tooth, forming a deposit of calcium fluoride that can act as a reservoir for the slow release of fluoride over time.

**Professional Slow Release Fluoride**

Methods to deliver small amounts of fluoride throughout the day are still being developed. Currently, materials such as silicate and glass-ionomer cements that contain between 15% to 20% fluoride are being used, and this amount of fluoride is also being added to composite and amalgam fillings. The concept is that these materials could provide a reservoir of fluoride to prevent secondary caries and to help remineralize caries in adjacent surfaces. Fluoride release begins high, but reduces as the available reservoir depletes.¹

Glass-ionomer cements are unique in that they are also able to absorb fluoride from other sources, such as toothpaste, and also slowly release this into the oral cavity, long after the fluoride that was originally placed in the glass-ionomer has dissipated. It should be noted, however, that clinical data on these methods of slow-release delivery have not yet confirmed the extent to which they are able to provide any therapeutic benefits.¹

**Conclusion**

Fluoride is an effective therapeutic and preventive agent for dental caries. The mineral alters the caries process by interfering with the dynamic of lesion development by enhancing remineralization, reducing demineralization, and inhibiting bacteria. While there are many forms of fluoride delivery, the incorporation of fluoride in a dentifrice has proven to be one of the most effective prevention and intervention strategies for dental caries. It should be noted that although fluoride therapy is important for caries control, it does not always stop caries development and progression. The tried-and-true public health recommendations of proper oral hygiene, such as brushing teeth at least twice a day, flossing to clean in between teeth, and cutting back on dietary sugar intake, continue to be very important in fighting caries.

**Video 3. How do you determine which preventive agent to use?**

*Click on image to view video online.*
1. **Which of the following is a key finding that led to the understanding of the benefit of fluoride in public dental health?**
   a. Children who lived in towns with abnormally high levels of fluoride in the water supply had perfectly healthy teeth.
   b. A new pipeline with an alternative water source pumped into the town of Oakley, Idaho, led to the disappearance of “brown stain” on teeth.
   c. Analysis of the water supply of Bauxite, Arkansas, uncovered an unusually high level of fluoride and this was confirmed in other towns with fluorosis.
   d. B and C

2. **The majority of fluoride ingested in water or food is absorbed in which body organ(s)?**
   a. Lymphatic system
   b. Kidneys
   c. Stomach and small intestine
   d. Liver

3. **The incorporation of fluoride into enamel structure is called _________.**
   a. hydroxyapatite
   b. apatite crystal
   c. fluorhydroxyapatite
   d. enameloxyapatite

4. **Which of the following is true about the concentration of fluoride in teeth?**
   a. Fluoride concentration is highest on surface enamel.
   b. Fluoride concentration is high in dentin.
   c. Fluoride accumulates over a lifetime at the dentin-pulp surface.
   d. All of the above.

5. **What is the main mechanism by which fluoride protects the tooth from caries?**
   a. Reduced demineralization and enhanced remineralization.
   b. Increased saliva production.
   c. Keeping enamel white.
   d. None of the above.

6. **Which of the following defines the mode of action for the antimicrobial effects of fluoride?**
   a. Inhibits growth and metabolism of *streptococci*.
   b. At higher concentrations, it can inhibit acid production by plaque bacteria.
   c. Interferes with the production of PEP, a bacterial energy source.
   d. All of the above.

7. **Chalky white lines or stains are believed to be caused by which of the following?**
   a. An abnormally high level of Streptococcus mutans in plaque.
   b. An abnormally high concentration of fluoride that leads to hypomineralization of tooth enamel.
   c. Excessive consumption of vitamin C.
   d. Excessive consumption of calcium.
8. What is the average percentage in caries reduction among children where community drinking water contains 1 ppm fluoride?
   a. 10%
   b. 30%
   c. 50%
   d. 90%

9. Which of the following research findings validates that consistent fluoride protection is needed to maintain a reduction in caries rate?
   a. Children who move from non-fluoridated areas to other non-fluoridated areas experienced a caries decrease.
   b. Children who move from fluoridated areas to non-fluoridated areas experienced a caries increase.
   c. Children who move from non-fluoridated areas to fluoridated areas experienced a caries increase.
   d. Children who move from fluoridated areas to non-fluoridated areas experienced a caries decrease.

10. Fluoride supplements are recommended for which population of people?
    a. Everyone
    b. Adults only regardless of caries risk.
    c. Children at high risk of caries residing in non-fluoridated areas.
    d. Children only regardless of caries risk.

11. How much fluoride does most over-the-counter dentifrice contain in the United States?
    a. 100 ppm to 200 ppm
    b. 850 ppm to 1150 ppm
    c. 3000 ppm
    d. 1 ppm

12. Which forms of fluoride are the most commonly used in dentifrice?
    a. Stannous fluoride
    b. Sodium fluoride
    c. Sodium monofluorophosphate
    d. All of the above.

13. Which of the following mechanisms explains why using a cup to rinse the mouth with water after brushing with fluoridated dentifrice is linked to more caries?
    a. Water makes fluoride more acidic.
    b. Water diminishes fluoride's ability to work as an antimicrobial.
    c. Water reduces saliva production.
    d. The large amount of water from using a cup as a rinsing aide flushes away the beneficial fluoride.

14. Which of the following types of fluoride should be recommended with caution due to the potential for it to cause pitting and etching of porcelain or composite restorations?
    a. Stannous fluoride
    b. Sodium monofluorophosphate
    c. Acidulate phosphate fluoride
    d. Sodium fluoride
15. **Which of the following is true about professionally applied fluoride varnish?**
   a. Used correctly, it is linked to a 38% reduction in caries.
   b. It forms a hardened deposit of calcium fluoride on the tooth acting as a reservoir for the release of fluoride over time.
   c. It usually contains about 22600 ppm of fluoride.
   d. All of the above.
References

About the Author

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Robert Faller has in excess of 38 years in the Oral Care Research field. He retired from P&G after more than 31 years in Oral Care, where he focused on caries and enamel related research as P&G’s chief cariologist. He is editor of *Volume 17 – Monographs in Oral Science: Assessment of Oral Health – Diagnostic Techniques and Validation Criteria*. He has written 3 book chapters, published 34 papers in peer-reviewed journals and has over 100 published abstracts on fluoride, caries, dental erosion, and various oral care technologies, along with 5 patents related to Oral Care and 6 Continuing Education courses. He currently resides in the UK and is a consultant to the Oral Care industry.

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