Caries Process, Prevention, and Management: Intervention

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- Dr. Apoena Aguiar Ribeiro reports no conflicts of interest associated with this course. She has no relevant financial relationships to disclose.

Short Description – Forensic Dentistry
This course is part 9 of a 10-part series entitled Caries Process, Prevention and Management. This course introduces the dental professional to the important role of fluoride in the prevention and control of dental caries.

Course Contents

Overview

This course is part 9 of a 10-part series entitled ***Caries Process, Prevention and Management***. 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 or caries-active patients.

Learning Objectives

Upon the 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 toothpastes 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)6 F2] resulting from the replacement of hydroxyl ions (OH-) in the hydroxyapatite structure with fluoride ions (F-). Fluorapatite (also commonly referred to as fluoroapatite, fluorhydroxyapatite or fluorohydroxyapatite) is stronger and more acid resistant than hydroxyapatite.

hydroxyapatite - Crystals of calcium phosphate - [Ca10(PO4)6 OH2] - 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.

hypo mineralization - 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 ingestion of an excessive amount of fluoride during the early stages of tooth development 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, and some who are adamantly against it.[1] 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.

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.

Brief History of Fluoride in Caries Control

The action of fluoride on or in the tooth can be split up into three primary mechanisms. The first mechanism is that fluoride, if it's present when the acids are produced by the bacteria, will go into the tooth at the same time or before the acid. It will stick or absorb on the surfaces of the tiny crystals inside the tooth, acting like a bodyguard and stopping the acid from dissolving the crystal surfaces. The second, and extremely important mechanism, is that if fluoride is present when the acid is neutralized, and that happens by the action of saliva in the mouth, then the fluoride together with calcium and phosphate from the saliva goes back into the tooth and remineralizes, or grows a new surface on those tiny crystals which is much more resistant. And the third important mechanism of action is that fluoride, if present among the bacteria on the tooth when they produce acid, that fluoride gets taken into the bacteria, slowing them down or even killing them. So those are the three primary mechanisms of action of fluoride, so-called "topical mechanisms" on the surface of the tooth.

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 pieces 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.[2] 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.[1,3] 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.[4] 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.[5,6]

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.[7-9]

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

Fluoride is incorporated into the inorganic part of enamel, the inorganic phase, by substitution for either hydroxyl ions or carbonate ions within the apatite lattice. In order for that to occur, in an already maturated or developed apatite crystal, there has to be some demineralization. So you have to have a demineralization and then the reverse, a reprecipitation will favor the incorporation of fluoride into the apatite crystal because fluoride is the most electro-negative of all elements and therefore bonds very firmly with calcium. The best time, the best time, for having this occur is actually right after tooth erupts. When a tooth erupts, it's not yet fully maturated, in other words, it's not yet fully calcified. It takes two more years for each tooth to calcify after it erupts into the oral cavity. That is the prime time for caries to occur because the tooth is very susceptible. It's also the best time to apply fluoride, whether that be fluoride in a dentifrice or professional fluorides, and that's true for both the primary dentition, the baby teeth, as well as the permanent dentition. So prematuration, post-eruptive, but prematuration is the best time to apply fluorides. That covers the period from two years of age up to about fifteen years of age, for different teeth in the oral cavity.

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 intestine. Fasting states (ingestion on an "empty stomach") increases fluoride absorption, while the intake of other dietary nutrients such as calcium, aluminum, and magnesium tends to decrease fluoride absorption. Most of the fluoride absorbed systemically that is not excreted via normal pathways (i.e., through the kidneys, the colon or by sweating) is deposited in mineralizing tissues such as bone and developing teeth. Fluoride is present in saliva at very low levels (0.01 ppm to 0.04 ppm) and in human milk at low levels (0.1 ppm). While the concentration of fluoride in these body fluids is minimal, studies show it is enough to impact dental caries.[1]

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 interface. 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]

Fluoride in Caries Protection and Fluorosis

Reduced Demineralization and Enhanced Remineralization

The anti-caries effect of fluoride is related to its ability to alter ionic saturation with respect to tooth mineral, thus, aiding remineralization of enamel crystals and preventing demineralization. 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

At high concentration, fluoride may interfere with bacterial metabolism and acid production by inhibition the bacterial **Enzyme** enolase, which interferes with the production of phosphoenolpyruvate (PEP).[10] 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 attained after use of prescription fluoride preparations—has also been found to inhibit acid production by most plaque bacteria.[11]

Fluorosis

Exposure to an abnormally high concentration of fluoride during the early stages of tooth development can lead 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 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.[1,12]

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.[13] 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]

It is important to recognize that the primary mechanism of fluoride in preventing dental caries is topical, not systemic. Although community water fluoridation was initially believed to work mainly by incorporating

Figure 1. Mild to Severe Dental Fluorosis

fluoride into developing tooth enamel during tooth formation, current evidence supports that its most significant caries-preventive benefit occurs after the teeth have erupted. When fluoridated water is consumed, fluoride remains in the saliva and plaque fluid, where it can continuously interact with tooth surfaces. This constant low-level exposure helps inhibit demineralization, enhances remineralization of early carious lesions, and inhibits bacterial activity in dental biofilm. Thus, the topical effect of fluoride—achieved even during and after ingestion of fluoridated water—may be its most important anticaries mechanism.[14]

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 in this country 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.[15] An additional study, in Jamaica, reported similar results in a 10-year study in that country.[16] 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.[17] 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 - Both the US Centers for Disease Control (CDC) and the American Dental Association (ADA) 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):[18]

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	0.25mg liquid drops	0	0
3 to 6 years	0.5mg drops or tabs	0.25mg	0
6 to 16 years	1mg	0.5mg	0

Table 1. Recommended Supplemental Fluoride Dosage Schedule.

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]

In many communities where water fluoridation is not available, fluoridated dentifrice are the major source of fluoride.[14] Regular toothbrushing using fluoridated dentifrice is the most rational way to administer topical fluoride because it puts in place two protective mechanisms; mechanical dental biofilm disruption and sustained fluoride delivery.[19]

Today, most 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 specially within the range in concentration from 1,000 to 2,500 ppm fluoride.[1,20,21] 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]

For patients 12 years or older, and with high caries activity or severe caries risk, 5,000 ppm F-toothpaste can be prescribed by the dentist. There is substantial evidence of the high-concentration fluoridated toothpastes in controlling caries progression, specially cavitated lesions and root caries lesions in elderly disabled people (lesions particularly difficult to control).[22,23] 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.[24] The fluoride action in inactivating demineralized lesions also lasts longer: at least for a couple of hours twice a day the fluoride concentration is 5 times higher in the saliva of those who use 5,000 versus those using 1,450 ppm F-toothpaste.[22] Since it is It is observed that the formation of calcium fluoride (CaF2) is concentration dependent and requires a

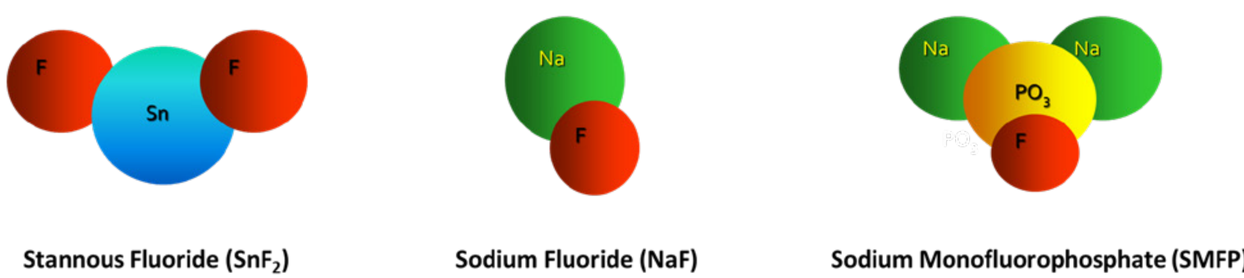

Figure 2. Common forms of Fluoride

concentration of >100 ppm fluoride to be formed.[25] the 5,000 ppm F-toothpaste provides a significant advantage over 1,100 and 1,450 ppm F-toothpaste in this sense. Therefore, the daily use of dentifrices containing 5,000 ppm F is more efficient in reducing active root caries lesions (dentin lesions) than dentifrices containing between 1,100 and 1,450 ppm fluoride.[23,26]

The most common forms of fluoride used in U.S. dentifrices are sodium fluoride (NaF), sodium monofluorophosphate (SMFP) and stannous fluoride (SnF_2). Mixtures of NaF and SMFP, NaF and SnF_2 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.

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.[27] 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.[28] While there 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.[1] 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.[1]

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 (Figure 3).

Figure 3. Recommendations for Fluoride Toothpaste in children.

Other Ingredients in Dentifrice

As mentioned before, regular toothbrushing using fluoridated dentifrice combines two protective mechanisms; mechanical dental biofilm disruption and sustained fluoride delivery. However, fluoride must be chemically free (soluble) in the toothpaste formulation, assuring F bioavailability in the oral cavity during toothbrushing.[29] This bioavailability depends on the chemical compatibility between the type of fluoride added to the formulation and the abrasive used.[30]

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.). In most developing countries the majority of the toothpastes contain calcium carbonate as abrasive, which may inactivate part of fluoride present in the commercial products, even if they are formulated with sodium monofluorophosphate (MFP).[31,32]

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, erosion protection and protection from oral malodor. Many **fluoride dentifrices** today cover some combinations or all of these benefit areas in one dentifrice.

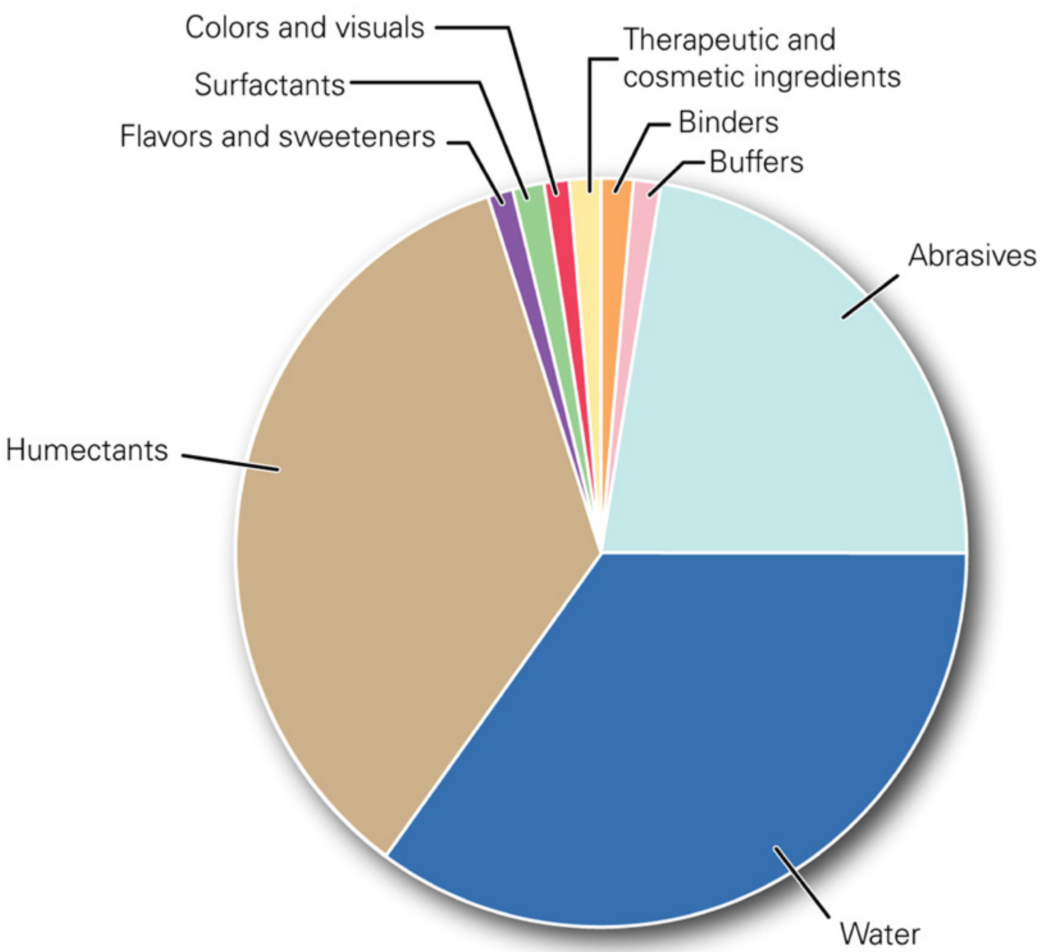

Figure 4. Other Toothpaste Ingredients

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.[1]

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.[1]

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%.[33] 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 5,000 ppm to 12,300 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.[33] 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 (22,600 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.[34] 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 Silver Diamine Fluoride (SDF)

It is the cariostatic material, efficient, conservative and less invasive than other treatments. The application of SDF according to various studies and protocols indicate that its application usually takes an average time of 60 seconds.[35] A recent Cochrane review showed that, in the primary dentition, current evidence remains inconclusive regarding the effectiveness of silver diamine fluoride (SDF) in preventing new caries or progression of existing lesions when compared to placebo or no treatment. SDF may be more effective than placebo or no treatment in arresting caries. It also prevents new root caries. However, the evidence is uncertain for other caries outcome measures in this dentition. For caries on coronal surfaces of permanent dentition, the evidence is also uncertain. When compared to fluoride varnish, SDF may offer little to no additional benefit in preventing new caries in the primary dentition, and evidence is highly uncertain regarding other caries outcomes and its preventive effects in the permanent dentition. Due to very low-certainty evidence, it was not possible to determine whether one SDF treatment regimen is superior to two or more SDF treatment regimens.

As adverse effects, tooth staining and metallic taste have been reported. However, reporting on tooth staining associated with SDF use was limited, and the evidence regarding adverse effects remains unclear.

Other Professional fluoridated cariostatic agents

a. Nanosilver Fluoride (NSF): Recently, through the use of nanotechnology, the addition of silver nanoparticles to dental products such as fluorides has been proposed Nanoparticles could control the formation of oral biofilm because of their biocidal and anti-adhesive microbial capabilities. Silver nanoparticles may be effective for controlling *S. mutans* and the antimicrobial effect is better when the nanoparticle is smaller than 10 nm. By combining the benefits of silver nanoparticles with fluoride, the nanosilver fluoride was described as a successful cariostatic material in a controlled clinical trial that showed effectiveness in paralyzing dentine caries in children from poor communities. Unlike silver diamine fluoride (SDF), the NSF did not show distinctive tissue darkening due to the oxidation of silver ions when in contact with the teeth. A recent randomized clinical trial showed that NSF represents an alternative remineralizing treatment for the management of carious lesions in the dentin of primary molars.[36]

b. Chlorhexidine modified with fluoride: Chlorhexidine is a potent broad-spectrum antimicrobial, and it can improve the adhesion of restorative materials to the tooth by inhibiting metalloproteinases, enzymes that degrade the bond between the two.[37] A new chlorhexidine-fluoride varnish product tested on *S. mutans* levels showed that the varnish significantly reduced *S. mutans* levels after four applications over 24 weeks. However, more clinical trials are needed to confirm their preventive effect on dental caries, mentioning that no adverse effects were reported.[38]

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.

Course Test Preview

To receive Continuing Education credit for this course, you must complete the online test. Please go to: www.dentalcare.com/en-us/ce-courses/ce718/start-test

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. Fluoride incorporates into the enamel structure as __________.

A. hydroxyapatite
B. apatite crystal
C. fluorapatite
D. enameloxyapatite

4. Which of the following is false 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 interface.
D. Fluoride only adsorbs onto the surface of the teeth; it does not penetrate into the teeth themselves.

5. What is the main mechanism by which fluoride protects the tooth from caries?

A. Fluoride helps to reduce demineralization and enhance remineralization.
B. Fluoride increases saliva production.
C. Fluoride helps keep tooth enamel white.
D. Fluoride is able to kill P. gingivalis bacteria, a major contributor to caries.

6. Which of the following is true regarding 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. Fluoride has no significant antimicrobial effects.
D. A and B

7. Chalky white lines 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, Potassium fluoride and Amine fluoride.
- B. Sodium fluoride, Stannous fluoride and Sodium monofluorophosphate.
- C. Sodium bi-fluorophosphate, Amine fluoride and Calcium fluoride.
- D. Sodium fluoride, Fluorapatite and Calcium fluoride.

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 NOT 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 1,100 ppm of fluoride.
D. Contain about 22,600 ppm of fluoride.

16. Which of the following statements best reflects current evidence regarding silver diamine fluoride (SDF) use in caries management?

A. SDF is conclusively proven to prevent new caries and stop progression in both primary and permanent dentition.
B. SDF has been shown to be ineffective in preventing root caries and offers no advantages over fluoride varnish.
C. SDF may help arrest caries and prevent new root caries, but evidence is uncertain for its effects on other outcomes and dentitions.
D. SDF application typically requires over 10 minutes and is associated with severe and well-documented adverse effects.

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Additional Resources

- No Additional Resources Available

About the Author

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Apoena De Aguiar Ribeiro is a Pediatric Dentist and Microbiologist. She was born in Rio de Janeiro, Brazil. Among her 25 years of teaching, Ribeiro most recently served as a tenured associate professor in the Fluminense Federal University, Department of Pediatric Dentistry and Cariology for 12 years, with a joint appointment at the Department of Microbiology for 5 years, in Rio de Janeiro State, Brazil. Prior to that role, she was an associate professor in the Grande Rio University Department of Pediatric Dentistry and Cariology for 8 years. During this time, she has also maintained a part-time role in a solo dental practice for 22 years, devoted to provide oral health to infants, children, adolescents and children with special needs. She is the author of a full book of Pediatric Dentistry (Pediatric Dentistry – A contemporary approach, GEN Editor, Brazil) and has published more than 50 papers in peer-reviewed journals. Dr. Ribeiro had successfully obtained 5 grants as a Principal Investigator in Brazil.

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