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Knowledge for Clinical Practice

CURRENT CONCEPTS IN Fluoride Therapy

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Foreword

The CE article contained in this supplement, 'Current Concepts in Fluoride Therapy' by Dr. Fiona Collins, provides an overview of fluorides.

Since the discovery that fluoride is an effective anti-caries agent and the introduction of fluoridated water in public water supplies, it is clearly evident that significant strides have been made not only in reducing caries in the general population but also in the understanding of the mechanisms of action of fluoride and delivery vehicles. Current evidence-based recommendations are used to develop individualized protocols for patients at risk for caries. This, of course, requires that risk factors and protective factors are identified for that patient to determine his or her risk level and an appropriate protocol for caries prevention and management. Current recommendations also consider total exposure to fluoride, balancing the benefits of the anti-caries mechanisms of action of fluoride with the risk of fluorosis associated with ongoing excessive ingestion of fluoride during tooth development.

This article contains a concise review of developments related to the use of fluorides in both professional fluorides and products intended for home use. Following an overview of the multifactorial nature of dental caries and the current concepts on the anti-caries mechanisms of action of fluoride, the focus turns to the efficacy and safety of professionally-applied fluorides, then over-the-counter and prescription level home use fluorides. The most recent recommendations for in-office fluoride use from the Council on Scientific Affairs of the American Dental Association are presented, as well as recommendations based on CAMBRA with respect to home-use fluorides. Current recommendations on the concentration of fluoride in public water supplies recommendations on when fluoride supplements should be given and at what dose. With respect to the use of individualized protocols, after defining risk factors for caries and protective factors that help control dental caries and prevent caries lesions, specific examples of moderate and high risk patients together with current evidence-based recommendations are presented in this review.

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Current Concepts in Fluoride Therapy

ABSTRACT

Current concepts on dental caries as a dynamic process, the mechanisms of action of fluoride, and the use of systemic and topical fluorides are based on a substantial body of research and evidence. Dental caries is a multifactorial bacterial infection, and all factors must be considered. In order to provide a patient with a suitable preventive program, the patient's risk level must be assessed and the program developed based on this and the age of the patient. Topical and systemic fluorides are safe and effective for caries control when used appropriately and are still considered the most effective method of controlling dental caries.

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Dr. Fiona M. Collins has authored and presented CE courses to dental professionals and students in the United States and internationally. She has been an active author, editor, speaker and consultant in the dental industry for several years, with clinical experience in general practice and academia as well as industry experience. She is a member of the American Dental Association and the Organization for Safety, Asepsis and Prevention, and has been a member of the British Dental Association, Dutch Dental Association, the International Assocation for Dental Research and the Academy of General Dentistry Foundation Strategy Board. Fiona is the CE Editor for Dental Learning. Fiona earned her dental degree from Glasgow University, was awarded the Alexander P. Husband Essay Prize, and holds an MBA and MA from Boston University. AUTHOR DISCLOSURE: Dr. Collins is a speaker on caries and prevention, and has received speaker support for courses from Premier Dental. Dr. Collins can be reached at fionacollins@comcast.net.

EDUCATIONAL OBJECTIVES

The overall goal of this article is to provide the reader with current concepts regarding the use of fluoride as a caries preventive. On completion of this article, the reader will be able to:

1. Describe the caries process
2. Review the mechanisms of action of fluoride for caries prevention
3. List and describe the types of topical fluorides that are available and their clinical efficacy
4. Review systemic fluorides, fluorosis and update dosing recommendations
5. Describe the factors responsible for orthodontic and xerostomic patients being at-risk for caries and review preventive treatment options.

Introduction

Topical and systemic chemotherapeutics have been used in dentistry for more than one hundred years and are currently used to prevent and/or treat a variety of oral diseases and conditions. Current concepts on dental caries as a dynamic process, the science behind fluoride, and topical and systemic recommendations for use are based on a substantial body of research and evidence.

Dental Caries – The Disease Process

Dental caries is a multifactorial bacterial infection involving primarily *Mutans streptococci* and *lactobacilli*. These bacteria colonize on the pellicle on the tooth surface, and produce extracellular polysaccharides that aid bacterial adhesion. Although multifactorial, without cariogenic bacteria dental caries cannot exist. It involves a dynamic process with repeated periods of demineralization (an 'acid attack')

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and remineralization over time, with the balance of these depending on conditions.[1] Demineralization occurs after acid is produced by cariogenic bacteria as they metabolize fermentable carbohydrates. Saliva is supersaturated with calcium and phosphate, preventing demineralization until the critical pH of <5.5 is reached. Subsurface dissolution begins at pH 3.8 – 4.8. Calcium, phosphate and carbonate ions are dissolved out of hydroxyapatite crystals.

Under favorable conditions, demineralization does not occur or is quickly followed by remineralization. Remineralization occurs as the pH rebounds, typically approximately 30 minutes after an acid attack, with calcium and phosphate (as well as fluoride) entering the demineralized sites. The actual timing depends on the availability and quality of saliva, and the depth of plaque present.

Under unfavorable conditions, repeated demineralization occurs either without or with insufficient remineralization. As enamel caries progresses, white spots may be visible as the underlying subsurface loses minerals (Figure 1). If oral conditions continue to favor demineralization, larger subsurface lesions will develop, breaching the enamodentinal junction, progressing into dentin and cavitating. Dentin is less dense than enamel, demineralizing more rapidly. In addition, following demineralization of dentin, the exposed dentin fibrils degrade enzymatically, increasing the rate of caries progression.[2,3]

Image courtesy of Dr. Howard E. Strassler

Figure 1. Decalcifications and white spots

Controlling Dental Caries

Caries lesions can be prevented/arrested/reversed by creating favorable conditions that inhibit demineralization and promote remineralization. Options include:

- Reducing or eliminating dental biofilm mechanically or chemotherapeutically
- Altering the biofilm to reduce cariogenic bacteria
- Chemotherapeutically inhibiting demineralization
- Chemotherapeutically promoting remineralization.

Fluoride continues to be considered the most beneficial topical agent.[4]

Fluoride: Anti-caries Mechanisms of Action

Fluoride exerts a potent anti-caries effect. Traditionally, the incorporation of systemically sourced fluoride into enamel hydroxyapatite crystals was held to be most important for caries prevention. Fluoride is incorporated during tooth development[5] prior to pre-eruptive enamel maturation. However, a higher concentration of fluoride is incorporated in the outer enamel layer compared to the inner layers (1,000–2,000 ppm vs. 20–100 ppm) – the result of being surrounded by fluoride-rich plasma during the pre-eruptive enamel maturation phase (a topical effect). These higher fluoride levels in the enamel do not correlate with decreased levels of caries.

Contemporary research has shown that the main effect of fluoride is topical. *Mechanisms by which this occurs are:*

- Bathing of erupted teeth in saliva and gingival crevicular fluid that contain fluoride (as a result of ingested fluoride, but a topical effect)
- Bathing of erupted teeth in fluoride as it is ingested/imbibed in foods and drinks
- Bioavailable fluoride
- Available fluoride remineralizes sites.

Topical fluorides result in bioavailable fluoride reservoirs intra-orally.[6] These reservoirs consist of calcium fluoride-like globules deposited at the tooth surface and in plaque, as well as free fluoride ions in plaque, saliva and on oral

mucosa.[7] Higher concentrations of fluoride favor calcium fluoride-like globules. Fluoride is also 'bonded' to bacteria or their fragments by calcium-fluoride bonds.[8] Bioavailable fluoride is also known as non-apatitically bound or loosely-bound fluoride.

When an acid attack occurs, calcium fluoride-like globules release calcium, fluoride and phosphate ions.[9,10] This is thought to occur as the lower pH breaks down the phosphate coating that otherwise maintains the stability of these globules. Released fluoride increases the concentration of fluoride in plaque and at the tooth surface.[10] Bioavailable fluoride then diffuses into the tooth together with calcium and phosphate ions, where it is incorporated into the hydroxyapatite crystals (becoming firmly bound or apatitically bound fluoride) and resulting in stronger, more acid-resistant crystals (Figure 2).[11] A dose response effect also exists with the use of topical fluorides. An additional mechanism for topical fluoride involves the inhibition of cariogenic bacterial activity, achieved when fluoride within bacterial cells inhibits enzymes required for the metabolism of fermentable carbohydrates (and acid production). Fluoride has also been shown to inhibit bacterial production of the extracellular polysaccharides that aid bacterial adhesion.[12]

The presence of small quantities of dental biofilm does not reduce the effect of fluoride therapy:

- Calcium fluoride-like globules form at the tooth surface in the presence of plaque
- Fluoride can penetrate through a light layer of plaque and concentrates within it.[13,14,15]

In summary, the topical effect of fluoride is now held to be key and is largely attributed to the presence of bioavailable fluoride. The use of fluoride agents must consider the risk level of an individual patient, the evidence for a given treatment, and other factors such as safety and convenience. Topical fluorides can be broadly categorized into professionally applied topical fluorides and home-use topical fluorides. Stannous fluoride, sodium fluoride, acidulated phosphate fluoride (APF) and sodium monofluorophosphate are all used in North America in professional and home-use products.

Professionally Applied Topical Fluorides

5% sodium fluoride varnish (22,600 ppm)

This is available in unit doses and tubes, with different flavors and viscosities and in white/clear/yellow-tinted variants. It has been investigated for childhood and adult coronal caries, root caries, secondary/recurrent caries, and for use around orthodontic brackets.

Efficacy and safety

Numerous clinical trials and studies support the use of 5% sodium fluoride varnish including:

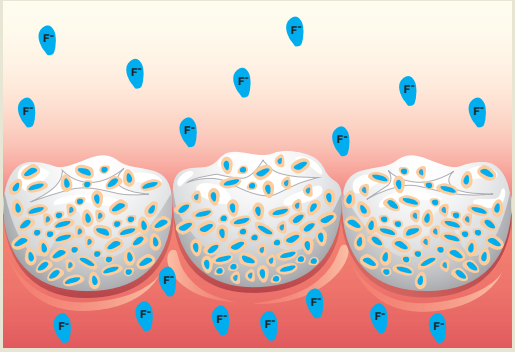

Figure 2a. Acquisition of calcium fluoride-like globules and free fluoride ions following use of topical fluoride

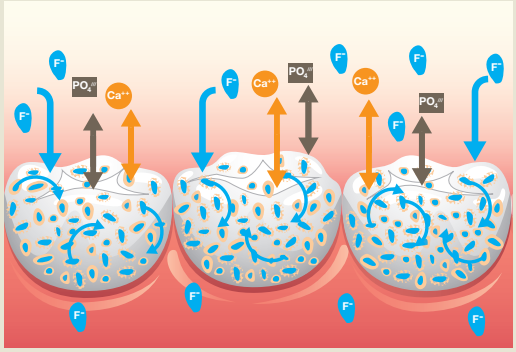

Figure 2b. Lower pH during acid attack results in demineralization and the release of ions from the teeth as well as the release of calcium, fluoride and phosphate from the calcium fluoride-like globules. These, together with the bioavailable free fluoride, remineralize the tooth as the pH rebounds.

- 33% caries reduction (range 19 – 48%) in the primary dentition (dmfs) in a meta-analysis of blind and double-blind clinical trials lasting a minimum of one year in the under-17 age group[16]
- 46% caries reduction (DMFS) (range 30 – 63%)[16]
- 38% caries reduction in children in a smaller, prior meta-analysis[17]
- Significant reductions in orthodontic decalcifications[18]
- Significant reductions in enamel decalcifications related to early childhood caries[19].

The total volume of fluoride applied is substantially less than with a gel or foam, and the varnish sets immediately on contact with saliva/water. Fluoride ingestion is substantially lower than that of a 4-minute gel.[20] Note, however, that the use of varnish for caries prevention/control is off-label in the United States, although globally this is its predominant use. Fluoride varnish is also available as a 0.9% difluorosilane (0.1% fluoride/1,000 ppm in solution). In a limited number of studies, including around orthodontic brackets[21], the researchers found it to be effective.

Neutral sodium fluoride (9,050 ppm) and APF (12,300 ppm) foams/gels

Gels and foams are applied in trays for 1 or 4 minutes. Compared to gels, foams use less product and total fluoride, with a lower likelihood of ingestion and a more pleasant patient experience. It is important to be sure that the foam being used does not shrink during use leaving surfaces uncovered.

Efficacy and safety

The efficacy of gels and foams has been investigated in a number of trials:

- 28% caries reduction (DMFS) with APF gel in a meta-analysis of blind and double-blind clinical trials lasting a minimum of one year in under-17s[16]
- 21% caries reduction (range 14 – 28%) in a meta-analysis of placebo-controlled clinical trials on gels[22]
- 22% average caries reduction in a systematic review of APF gel trials[23]
- Smooth surface caries reductions averaging 41% with APF foam/gel in a 2-year trial in 6-7-year-olds[24]
- 24% caries reduction (dmfs) with twice-annual application of APF foam in 4-year-olds (efficacy was shown only on approximal surfaces)[25].

Although there is insufficient evidence to recommend their use, recent *in-vitro* and *in-situ* studies suggest 1-minute gels/foams may be as effective as 4-minute treatments.[26]

pH and topical fluorides

Low pH formulations were developed with the objec-

TABLE 1. Recommendations for professionally-applied topical fluoride based on risk level[31]

	<6 years of age	Age 6 -18	Over age 18
Low risk*	May not be of benefit	May not be of benefit	May not be of benefit
Moderate risk**	Fluoride varnish two times per year	Fluoride varnish or gel 2 times per year	Fluoride varnish or gel 2 times per year
High risk***	Fluoride varnish 2 - 4 times per year	Fluoride varnish or gel 2 - 4 times per year	Fluoride varnish or gel 2 - 4 times per year

*Low risk: Patients with no risk factors, including no incipient/cavitated/secondary caries lesions in the prior 3 years
** Moderate risk under age 6: Patients with ar least one risk factors, but no incipient/cavitated/secondary caries lesions in the prior 3 years
** Moderate risk age 6+: Patients with ar least one risk factors and/or 1 or 2 incipient/cavitated/secondary caries lesions in the prior 3 years
*** High risk under age 6: Patients with multiple risk factors and/or any incipent/cavitated lesion in the prior 3 years
*** High risk age 6+: Patients with multiple risk factors and/or 3 or more incipent/cavitated lesion in the prior 3 years

tive of increasing fluoride uptake. Since demineralized enamel takes up more fluoride than sound enamel,[27] using a low-pH fluoride *de facto* results in greater fluoride uptake. It is, however, it is bioavailable fluoride that is now recognized as being most important. Low-pH fluorides may be unsuitable for certain patients: these may alter the titanium surfaces of implants,[28] and a high-concentration may increase bacterial colonization and inhibit epithelial junction development.[29] With ongoing use, low-pH products may have the potential for roughening composites and glass ionomers.[30]

2% sodium fluoride rinses (9,050 ppm) and dual rinses (3,300 ppm)

Limited clinical evidence exists for 2% sodium fluoride.

- Average caries reduction (DMFS) of 29% with sodium fluoride solution use in the under-17 age group[16]

No clinical evidence exists for the use of dual rinses.

Current recommendations for professionally-applied topical fluorides[31]

The recommendations of the ADA Council on Scientific Affairs are presented in Table 1. For low risk patients, a fluoride dentifrice may offer sufficient protection, although clinical judgment should be used to determine whether an in-office topical fluoride is necessary.

Over-the-counter (OTC) Topical Fluorides

Fluoride dentifrices

Dentifrices in the United States and Canada usually contain 1,000 – 1,100 ppm fluoride, available as 0.23 – 0.24% sodium fluoride, 0.4% stannous fluoride or 0.70% sodium monofluorophosphate. These are all effective and are recommended for twice-daily use.

Efficacy

Fluoride dentifrice efficacy in the primary and permanent dentition has been demonstrated worldwide:

- 23% average caries reduction (DMFS) in a meta-analysis of 74 controlled trials at the concentration of 1,000 – 1,250 ppm in the 16-and-under age group[32]
- 24% (range 21 – 28%) average caries reduction (DMFS) in a meta-analysis of 70 controlled, blinded trials in the 16-and-under age group[33] with the higher caries reductions in high-risk patients
- 67% root caries reduction (DFS) in a 1-year study[34]
- No statistically significant caries reduction with use of dentifrices containing 450 – 550 ppm[35].

Current recommendations: 1,000 – 1,100 ppm dentifrices

- Children age 2 until age 6: Use of a pea-sized amount twice daily, brushing under supervision (rinsing and expectorating after brushing)[36]
- Age 6 onward: Twice-daily brushing with toothpaste; may require supervision until age 10 or 11

Fluoride rinses

Over-the-counter fluoride rinses are available as sodium fluoride and as acidulated phosphate fluoride/sodium fluoride (pH ~4). Options include 0.05% or 0.02% sodium fluoride and 0.044% or 0.21% APF. These concentrations fall under the FDA caries monograph. A recent meta-analysis confirmed that rinsing with fluoride resulted in a reduction in dental caries.[37] Clinical trials have been published using 0.05% sodium fluoride and 0.044% APF rinses.

Efficacy of 0.05% sodium fluoride rinse

- 84% caries arrestment rate for noncavitated smooth surface caries lesions with daily rinsing in the 11 – 15 age group[38]
- Reductions in orthodontic white spot lesions with daily rinsing[39]
- Substantial reductions in root caries in geriatric patients in a 4-year study[40]
- 31% caries reduction with daily rinsing in non-fluoridated communities[41]

Efficacy of 0.044% acidulated phosphate fluoride rinse

- Up to a 58% reduction in orthodontic white spots[42]

Current directions for OTC fluoride rinses

- Fluoride rinses are not recommended for the under-6 age group, due to the risk of swallowing (see below)
- 0.05% sodium fluoride and 0.044% acidulated phosphate fluoride are recommended for daily use
- 0.02 – 0.21% fluoride rinses must be used twice daily
- Plaque and salivary fluoride levels are higher with the use of higher-ppm fluoride rinses[43]
- Nighttime use results in prolonged fluoride retention in whole saliva compared to daytime use[44]

Recent investigations suggest a role for fluoride rinsing post-brushing. Rinsing with water after brushing lowers the level of bioavailable fluoride and fluoride rinsing has been proposed.[45,46,47,48] A small study found that rinsing post-brushing with water/100 ppm fluoride reduced salivary fluoride ('wash-out') whether 5,000 ppm or 1,450 ppm fluoride dentifrice had been used. 0.05% sodium fluoride rinse resulted in a significantly greater level of salivary fluoride than just brushing, and 900 ppm (0.2% prescription level rinse) even more so.[49]

Prescription Home-use Pastes, Gels and Rinses

1.1% sodium fluoride (5,000 ppm) pastes/gels

These confer additional protection due to a dose-response effect. Gels/pastes can be used in fluoride mouth-trays; however, they are now mainly used during brushing, which is preferable for patient compliance. Pastes offer the additional advantage of including an abrasive for gentle cleaning while brushing with them (instead of a dentifrice).

Efficacy of 1.1% sodium fluoride paste/gel

- 57% remineralization of root caries lesions over a 6-month period with twice-daily brushing[50]
- 91% root caries arrestment rate over a 1-year period when used in trays[51]
- Effective in helping to prevent caries lesions following head and neck radiation[52]

Current directions for 1.1% sodium fluoride

- Not recommended for children under age 6
- Recommended for twice-daily use in patients at high risk for caries[53]
- Patients should expectorate after use, not rinse, to maintain a higher level of bioavailable fluoride[13]

0.2% sodium fluoride rinse (920 ppm)

0.2% sodium fluoride rinse has been used in school programs on a weekly basis. It is not intended for use in children under age 6 (due to the risk of fluorosis).

Efficacy of 2% sodium fluoride rinse

- Up to 55% caries reduction in schoolchildren with once-weekly rinsing over 30 months[54]
- 57.8% caries reduction (DMFS) over 7 years with weekly rinsing (it was concluded, however, that other factors also contributed to this)[55]

0.63% stannous fluoride rinse

These are diluted for use, rendering a concentration of 0.1% stannous fluoride. This rinse is less frequently used. It has demonstrated caries reductions and inhibition of bacterial metabolism.[56]

Fluorosis

Fluorosis results from the *ingestion* of excessive cumula-

Figure 3. Moderate fluorosis

Image courtesy of Dr. Ted Croll

tive amounts of fluoride during tooth development prior to pre-eruptive enamel maturation. (Figure 3) Sources include fluoridated water, supplemental fluorides, infant formulas, infused tea, foods, and some medications. Fluoride is also ingested unintentionally during toothpaste and rinse use.[57] *Topical fluorides may be associated with fluorosis only if they are swallowed over a period of time, prior to pre-eruptive enamel maturation. There is no evidence that in-office topical fluorides – which are infrequently used – play a role in fluorosis.*[58]

Fluorosis can present in the following ways:[59]

- Mild fluorosis that appears as white lacy striae
- Moderate fluorosis with mottled areas of hypomineralization over >50% of the enamel
- Severe fluorosis with abnormal tooth morphology, brittle enamel, severe brown staining and pitting. This is typically due to well water with an extremely high fluoride level (e.g., 9–10 ppm), and was observed by this author in the Middle East
- In all cases, hypomineralization is present.

The risk of fluorosis is mainly of concern up to age of 6, by which time most of the dentition has undergone pre-eruptive enamel maturation, and after age 8 is of no concern. Appropriate use and dosing of systemic fluorides helps to reduce the risk of fluorosis associated with excessive cumulative ingestion from all sources of fluoride.

Infant formula

A recent study of infant formulas determined that:[60] 1) most infants will receive excess fluoride (above the recommended level) if formula is reconstituted with water at 1 ppm; and 2) for some formulas, a water level of 0.5 ppm will result in excess fluoride ingestion. It was also determined that excess fluoride content was unlikely to be reached if 1) ready-to-use infant formula was given; 2) liquid infant formula was given; and 3) infant formula was reconstituted with water <0.4 ppm fluoride.

Systemic Fluorides

Fluoridated water supply

An intentionally fluoridated water supply was first introduced in the mid-1940s in the United States and Canada.[61,62] As discussed above, current concepts hold that the effect of systemic fluorides is mainly topical – in communities where the public water supply was no longer fluoridated, increases in caries were observed – including in the dentition of patients who had always lived in that community.[63] Water fluoridation is considered the most effective caries preventive at the community level.[64]

Other systemic fluorides

Fluoridated milk, drinks and salt have also been used in some regions. One 3-year study demonstrated a statistically significant caries reduction in children drinking fluoridated milk.[65] A meta-analysis of salt fluoridation studies found caries reductions in children.[66] Supplemental fluoride drops, lozenges and tablets may also be used. It is then recommended to suck lozenges or crunch tablets so that the

TABLE 2. Recommended fluoride supplement dosing[69]

	6 months - 3 yrs	3 to 6 yrs	6 yrs to at least 16 yrs
Water fluoride level			
< 0.3 ppm	0.25 mg	0.50 mg	1 mg
0.3 - 0. 6 ppm	0 mg	0.25 mg	0.50 mg
> 0.6 ppm	0 mg	0 mg	0 mg

Fluoride supplements are not recommended, regardless of age or risk level, if the water fluoride level is < 0.6 ppm.

maximum topical benefit is obtained. A recent review of 11 studies found limited evidence for childhood caries prevention using fluoride supplements, although caries reductions were observed in the permanent dentition in children under 16 years of age.[67]

Updated recommendations for systemic fluoride use

Due to an increased overall availability of fluoride, mild to moderate fluorosis has become more prevalent. Revised recommended doses have been introduced to balance the benefits of fluoride use with the risk of fluorosis:

- The recommended concentration of fluoride in public water supplies is now 0.7 ppm fluoride[68]
- Fluoride supplements are recommended by the American Academy of Pediatric Dentistry (AAPD), the ADA and the American Academy of Pediatrics only for at-risk children.[69] If thus indicated, fluoride supplements should commence only at 6 months of age.

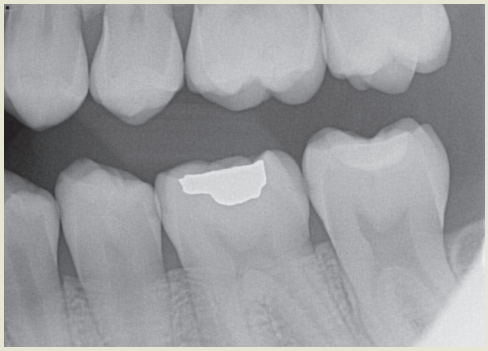

Image courtesy of Dr. Michael Skramstad

Figure 4. Enamel lesions mesially and distally

Identifying At-risk Patients

The strongest predictor of future caries is past caries experience.[70] Disease indicators include white spots (associated with caries) on smooth surface enamel, recent restorations (within the last 3 years) as a result of dental caries, enamel lesions mesially and distally (radiographically evident) (Figure 4), and cavitated caries lesions (radiographically evident).

Dental caries will progress if the influence of pathologic factors is greater over time than that of protective factors.[71] Risk factors relate to the level of cariogenic bacteria, the ability to inhibit demineralization and to promote remineralization, lifestyle/habits, systemic factors and local environmental factors (Table 3). Severe early childhood caries (Figure 5) is now thought to be a distinct entity presenting with an early, less diverse bacterial colonization and with enamel hypoplasia (due to prenatal insult) that provides surface defects for colonization.[72]

Protective factors include saliva, exposure to fluoride and other anti-caries agents, and lifestyle (Table 4).

Saliva washes fermentable carbohydrates from the teeth and oral cavity, and buffers the pH, thereby neutralizing bacterial acid. In addition, saliva contains statherin, lacto-

Image courtesy of Dr. Sarita Arteaga

Figure 5. Severe early childhood caries

Figure 6. Ex-orthodontic patient with poor compliance

ferrin, immunoglobulins and other agents that are protective.[73] Ductal saliva carries small quantities of fluoride and calcium, while whole intra-oral saliva acts as a substantial fluoride reservoir.[74] This fluoride is then available for incorporation into dental plaque.

In order to recognize and appropriately treat patients, a caries risk assessment should be performed. Numerous standardized caries risk assessment tools are available, including the following: (1) CAMBRA (CAries Management By Risk Assessment), which includes a form to determine the risk

TABLE 3. Destructive/pathologic risk factors.[75,76,77,78]

Factor	Mechanisms
Poor oral hygiene	Increases bacterial load
High level and frequency of fermentable carbohydrates	Increases opportunity for repeated, greater acid production
Familial high caries rate	Bacterial transmission; environmental factors
Xerostomia	Loss/decrease of protective factors related to saliva
Suboptimal fluoride exposure	Reduced ability to prevent demineralization/reverse
Enamel defects	Niches for bacteria; areas of dysmineralization
Defective restorations	Niches for bacteria; may also include exposed dentin
Exposed roots	Dentin exposure - susceptible to rapid caries progression
Orthodontic appliances	Niches for bacteria; difficulty performing oral hygiene
Tobacco use/drug or alcohol use	Fermentable carbohydrates in chew tobacco; influence on bacterial balance and dry mouth
Low SES	Poor diet; less knowledge; irregular dental visits
Genetics	Influence on bacterial load; level and quality of saliva; tooth development/dysmineralization

TABLE 4. Protective factors

Factor	Mechanisms
Saliva	Removes, carbohydrates, bacteria; buffers pH; supplies fluoride, calcium, antibacterial agents
Fluoride exposure	Inhibits demineralization and promotes remineralization
Use of xylitol	Cariogenic bacteria cannot metabolize xylitol thus no acid production; starvation effect on bacteria
Antimicrobial agents (incl xylitol)	Reduce the level of cariogenic bacteria;
Sealants	Protect pits and fissures; may/may not release fluoride
Healthy lifestyles	Reduce exposure to destructive factors

level along with recommendations based on an individual's risk level and age (2) Cariogram, a downloadable program (3) ADA forms for 0 to 6 years of age and for ages 6 and over (4) AAPD forms.

Risk assessment forms include a list of specific destructive and protective factors from which the clinician selects the status for an individual patient, and also address caries experience. Depending on the tool, a numeric score may be generated based on the individual's risk factors. Since a patient's risk level is not static, a risk assessment must be repeated at regular intervals. The AAPD recommends that the first risk assessment be performed by 6 months of age.

Several categories of patients are by definition at-risk patients, including orthodontic and xerostomic patients. These two examples are discussed below.

Young children

Young children under age 6 who are at risk can develop early childhood caries (at least one lesion present under age 6) or severe early childhood caries that is rampant and destructive.

Topical fluoride therapy for young children under age 6

Recommendations for at-risk patients under age 6 are as follows:

- Fluoride varnish every 6 months for moderate risk, and 2 to 4 times per year for high-risk patients
- Age-appropriate OTC fluoride dentifrice use
- Topical fluoride rinses are NOT recommended due to the risk of swallowing and fluorosis.

Orthodontic patients

Greater bacterial colonization occurs on orthodontic appliances and teeth with brackets and ligatures/bands compared to other teeth. Fixed orthodontic appliances (FOAs) make oral hygiene more complex.[79] Orthodontic decalcifications ('white spots') occur with frequency adjacent to brackets and may present within 1 month of the onset of treatment.[80] It was previously estimated that up to 50% of patients could develop white spots in the absence of a preventive program.[81] In a more recent study using quantitative light-induced fluorescence 97% of subjects had lesions and an average of 30% of buccal surfaces were affected by caries.[82] In a 2012 survey, 69% of general dentists had treated orthodontic white spots, and 37% of orthodontists had removed FOA due to poor patient compliance with oral hygiene (Figure 6). The researchers recommended fluoride therapy and low-concentration topical fluorides post-treatment.[83]

Topical fluoride therapy for orthodontic patients

Recommendations for at-risk patients (includes orthodontic patients), are as follows for age 6 and over:

- Fluoride varnish or gel every 6 months for moderate risk, and 2 to 4 times per year for high-risk patients.
- Home-use topical fluoride:
  - For patients with no cavitated lesions, twice-daily OTC dentifrice use and daily use of 0.05% sodium fluoride rinse[53]
  - For patients with cavitated lesions, 1.1% prescription-strength sodium fluoride paste/gel[53]

Daily use of 0.05% fluoride rinse inhibits enamel lesions adjacent to FOA.[39,84]

Xerostomic patients

Xerostomic patients are considered high-risk (extreme high risk). Etiologies include prescription drug use, autoimmune diseases as well as head and neck radiation. The importance of xerostomia in the progression of dental caries can easily be understood considering the functions of saliva.[85] Patients with xerostomia experience a longer dip in pH than other patients, with the pH remaining below the critical level for demineralization for extended periods of time. Greater accumulation of biofilm and bacteria occurs, calcium and phosphate that help prevent demineralization are absent or reduced, buffering capacity is lost and other protective factors are either reduced or absent.

Topical fluoride therapy for patients with xerostomia

Evidence-based recommendations are as follows for age 6 and over:

- In-office fluoride varnish or fluoride gel 2 to 4 times per year
- Home-use topical fluoride:
  - 5,000 ppm fluoride paste/gel once- or twice-daily (if once daily, fluoride dentifrice should be used the second time daily) AND daily use of a 0.05% sodium fluoride rinse as well as when the mouth feels dry or after eating/drinking.[53]

Under age-6 should receive fluoride varnish treatments, but not fluoride rinse.

Summary

Fluorides are the first line of defense on the chemotherapeutic control of dental caries. The efficacy and safety of, in particular, professional and home-use topical fluorides is well-established based on the evidence. Fluoride use for an individual patient should be evidence-based and must consider his/her level of risk, as determined by disease indicators and risk factors, and the age of the patient. Other factors to consider include patient compliance, convenience and ease of use.

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CEQuiz

1. **Current concepts on dental caries and recommendations for the use of fluoride are based on _____.**
   a. learned opinions
   b. a substantial body of research and evidence
   c. the FDA
   d. none of the above

2. **Bacteria that colonize the tooth surface produce extracellular polysaccharides that _____.**
   a. produce acid
   b. aid bacterial migration
   c. aid bacterial adhesion
   d. a and b

3. **During the caries process, subsurface dissolution begins at a pH of _____.**
   a. 2.5 – 3.5
   b. 2.8 – 3.8
   c. 3.5 – 4.5
   d. 3.8 – 4.8

4. **As enamel caries progresses, white spots may be visible as the _____ loses minerals.**
   a. surface
   b. underlying subsurface
   c. cementum
   d. dentin

5. **In one meta-analysis of blind and double-blind clinical trials, a _____ caries reduction in the primary dentition and a _____ caries reduction in the permanent dentition was found.**
   a. 23%; 36%
   b. 25%; 33%
   c. 33%; 46%
   d. 38%; 42%

6. **During tooth development, fluoride is incorporated into the hydroxyapatite crystals prior to _____.**
   a. pre-eruptive enamel maturation
   b. post-eruptive enamel maturation
   c. surface solidification
   d. all of the above

7. **Topical fluoride use results in bioavailable fluoride reservoirs intra-orally that consist of _____.**
   a. calcium fluoride-like globules deposited at the tooth surface and in plaque
   b. free fluoride ions in plaque, saliva and oral mucosa
   c. apatitically bound fluoride
   d. a and b

8. **Contemporary research has shown that the main effect of fluoride is _____.**
   a. systemic
   b. topical
   c. negligible
   d. all of the above

9. **When an acid attack occurs, calcium fluoride-like globules release _____ ions.**
   a. calcium
   b. phosphate
   c. fluoride
   d. all of the above

10. **Fluoride incorporated into hydroxyapatite crystals is also known as _____ fluoride.**
    a. firmly bound
    b. apatitically bound
    c. reserve
    d. a and b

11. **Fluoride _____.**
    a. can concentrate within light plaque
    b. is deflected by plaque
    c. must be used before brushing
    d. cannot penetrate through light plaque

12. **Five percent sodium fluoride varnish has been investigated for the prevention of _____.**
    a. coronal caries
    b. root caries
    c. secondary/recurrent caries
    d. all of the above

13. **Dentin _____.**
    a. is less dense than enamel
    b. contains dentin fibrils that degrade enzymatically
    c. is more rapidly demineralized than enamel
    d. all of the above

14. **Fluoride varnish is available as _____.**
    a. 0.3% fluoroxane
    b. 0.9% difluorosilane
    c. 5% sodium fluoride
    d. b and c

15. **Compared to gels, foams _____.**
    a. use less product
    b. offer a more pleasant patient experience
    c. use less total fluoride
    d. all of the above

CE QUIZ

16. A caries reduction (DMFS) of _____ was found in a meta-analysis of trials where APF gel was used.
a. 18%
b. 28%
c. 38%
d. 48%

17. Low pH fluride formulations were developed with the objective of _____.
a. increasing application time
b. increasing fluoride uptake
c. increasing fluoride concentration in the product
d. all of the above

18. For low risk patients, _____.
a. a fluoride dentifrice may offer sufficient protection
b. clinical judgment should be used to determine whether an in-office topical fluoride is necessary
c. supplemental fluoride is required
d. a and b

19. Clinical trials have been published using _____ over-the-counter rinses.
a. 0.2% sodium fluoride and 0.05% sodium fluoride
b. 0.2% sodium fluoride and 0.044% APF
c. 0.05% sodium fluoride and 0.044% APF
d. 0.05% sodium fluoride and 0.01% APF

20. Fluoride rinses_____.
a. are recommended for all age groups
b. are not recommended for the under-6 age group
c. should only be used in low-risk patients
d. none of the above

21. _____ acts as a substantial fluoride reservoir.
a. Ductal saliva
b. Whole intra-oral saliva
c. Gingival crevicular fluid
d. all of the above

22. Fluorosis results from the ingestion of excessive cumulative amounts of fluoride _____.
a. during tooth development prior to the pre-eruptive enamel maturation phase
b. from supplemental fluorides only
c. during office visits
d. all of the above

23. The risk of fluorosis is mainly of concern up to age _____, and after age _____ is of no concern.
a. four; six
b. five; seven
c. six; eight
d. seven; nine

24. 1.1% sodium fluoride (5,000 ppm) pastes and gels confer additional protection compared to lower level fluoride products due to _____.
a. their uptake mechanism
b. a dose response effect
c. their viscosity
d. all of the above

25. The recommended concentration of fluoride in public water supplies is now _____ fluoride.
a. 0.7 ppm
b. 0.9 ppm
c. 1 ppm
d. 1.2 ppm

26. Caries risk factors relate to _____.
a. the level of cariogenic bacteria
b. the ability to inhibit demineralization and to promote remineralization
c. systemic, local and environmental factors
d. all of the above

27. Fixed orthodontic appliances make oral hygiene more complex, and orthodontic decalcifications may present within _____ of the onset of treatment.
a. one day
b. one week
c. one month
d. none of the above

28. Recommendations for at-risk patients age 6 and over include _____.
a. fluoride varnish or gel every 6 months for moderate risk patients, and two to four times per year for high risk patients
b. twice-daily OTC dentifrice use and daily use of 0.05% sodium fluoride rinse for patients with no cavitated lesions
c. 1.1% sodium fluoride paste/gel use for patients with cavitated lesions
d. all of the above

29. Patients with xerostomia _____.
a. are at high risk for caries
b. experience a longer period of time during which demineralization can occur following an acid attack
c. do not have, or have reduced, buffering capacity and protective factors
d. all of the above

30. Fluoride use for an individual patient _____.
a. should be evidence-based
b. must consider his/her caries risk level
c. must consider the age of the patient
d. all of the above

CE ANSWER FORM (E-mail address required for processing)

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EDUCATIONAL OBJECTIVES

- Describe the caries process
- Review the mechanisms of action of fluoride for caries prevention
- List and describe the types of topical fluorides that are available and their clinical efficacy
- Review systemic fluorides, fluorosis and update dosing recommendations
- Describe the factors responsible for orthodontic and xerostomic patients being at-risk for caries and review preventive treatment options.

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Pit and Fissure Sealants in the Prevention of Caries

Introduction

The prevalence of dental caries varies by age group, population subset and tooth surface, and increases with age. In the US, approximately 41% of children experience dental caries in the primary dentition, and 42% ages 6-19 experience dental caries. Children from low-income families disproportionately experience dental caries and untreated caries lesions. Furthermore, occlusal caries represents 80-90% of caries in permanent posterior teeth and 44% in primary molars. Dental caries is multifactorial – and can only exist when cariogenic bacteria and fermentable carbohydrates are present.

Given that the acid associated with caries-related demineralization is produced by cariogenic bacteria metabolizing fermentable carbohydrates, it stands to reason that preventing cariogenic bacterial growth in pits and fissures, and/or preventing the bacteria from accessing fermentable carbohydrates, could prevent dental caries and its progression. Pit and fissure sealants are an effective intervention for the prevention of pit and fissure (mainly occlusal) caries, available as light-cured, dual-cured or self-cured resin-based materials and as glass ionomers. Overall, the most recent NHANES study found that 32% of children aged 6—19 years had received dental sealants while a survey of Northwest PRECEDENT dental network reported on in 2011 found that 27% of patients up to the age of 17 received sealants.

Anti-caries efficacy of pit and fissure sealants

Caries reductions of up to 90% have been reported with the use of fissure sealants when recall appointments and maintenance were included. In one study, 73% of sealed permanent molar occlusal surfaces were caries-free (vs. 23% of untreated surfaces) nine years after sealant placement. Sealants can halt the progression of incipient caries lesions and do not lead to the growth of bacteria trapped under the sealant during placement (and subsequently to caries). In fact, they can lower salivary levels of mutans streptococci following placement in caries-free environments. As with fluorides, the greatest benefit is seen at higher levels of risk. Sealant placement is also cost-effective in high-risk disadvantaged patients.

Studies have assessed occlusal caries reductions with pit and fissure sealants compared to fluoride varnish (which has demonstrated efficacy against occlusal caries). A recent review of four studies found evidence that pit and fissure sealants have greater anti-caries efficacy than varnish for the occlusal surfaces of first permanent molars - in three of the four studies, statistically significant differences were found. One 4-year program of sealant or varnish placement on permanent first molars (ages 6 to 8 years) followed by a 5-year period during which no sealants or fluoride varnish were provided. Compared to control, at year 9 caries reductions were 65% for the sealant group and 27% for the varnish group. Trials are currently underway comparing the cost and effectiveness of fissure sealants compared to fluoride varnish.

Evidence-based recommendations

The American Academy of Pediatric Dentistry and The American Dental Association Council on Scientific Affairs (2008) recommendations for pit and fissure sealants include:

- Placement on permanent first and second molars when the tooth or patient is at risk for caries, independent of age of the patient
- Placement on primary molars if a child or the tooth is at risk for caries
- Placement on incipient (early noncavitated) caries lesions to halt their progression.

Sealants should ideally be placed when teeth are newly-erupted, and after placement should be monitored regularly (and teeth resealed if necessary). The evidence also led to the conclusion that resin-based sealants are preferable to glass ionomer cements, except in situations where moisture control is inadequate for placement of a resin-based sealant.

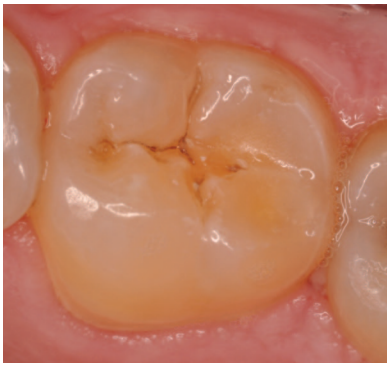

Figure 1. Lower molar with early (noncavitated) caries lesion

Patients should still receive in-office topical fluorides appropriate for their caries risk, and use home fluorides that are also caries risk level-appropriate.

Placing pit and fissure sealants

Pits and fissures should be cleaned to remove biofilm and debris prior to sealant placement. As with other products, the manufacturer's recommendations and instructions for use for the specific product should be followed.

Placement of resin-based sealants

Retention of resin-based sealants requires etching of the enamel prior to sealant placement, to provide for micro-mechanical retention of the sealant which forms tags in the etched enamel. The area must be dry during placement and until the sealant has cured. Adhesive agents may be used to improve retention, depending on the sealant and clinical preference, and are available as 1) etch-and-rinse (total etch) products with bonding agents; 2) self-etch systems with a separate adhesive; and 3) self-adhesive systems requiring only one step. Recently, hydrophilic pit and fissure sealants have also been introduced. Enameloplasty (fissurotomy) procedures have not been shown to improve results.

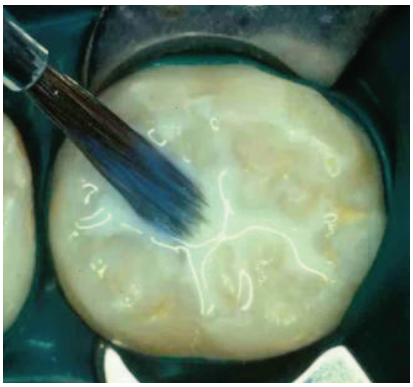

Figure 2. Resin-based pit and fissure sealant

Placement of glass ionomer sealants

Glass ionomers do not require etching or bonding, although an enamel conditioner may be used prior to sealant placement. These sealants are moisture tolerant and self-adhesive - this can be advantageous in young children, especially when lower posterior teeth are at-risk and are barely clear of the operculum. Although studies have shown these sealants to have lower retention rates and efficacy than resin-based sealants, recent reviews have found the anti-caries efficacy of resin-based and glass ionomer sealants to be similar. Higher quality randomized trials have been recommended for the future for comparisons.

Summary

In accordance with evidence-based recommendations and with clinical judgment, increased use of pit and fissure sealants would help at-risk patients and provide cost-effective reductions of occlusal caries. Pit and fissure sealants they are an important component of a caries prevention program for at-risk patients, as is risk- and age-appropriate use of topical fluorides.

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