INTRODUCTION TO DENTAL CARIES

Dental caries, commonly known as cavities or tooth decay, is one of the most common dental conditions. This disease affects the hard tissues of the teeth and is caused by exposing teeth to cariogenic bacteria - micro-organisms that are responsible for causing caries - in combination with fermentable carbohydrates. The resultant interaction increases organic acids which dissolve the carbonated hydroxyapatite mineral of teeth enamel.

A healthy equilibrium in the mouth can help combat caries, and one of the most important substances necessary for balance and improved dental health is the mineral fluoride.

DENTAL CARIES IN CHILDREN AND ADULTS

Dental caries in children has significantly declined over the last two decades in the Western world, but the disease continues to cause major complications and discomfort for adults and children everywhere.

70% of children between 12 and 17 years of age have caries.

94% of all dentate adults above the age of 18 have either treated or untreated cavities.

Since untreated dental caries can lead to pain, discomfort and even tooth loss it is important to find ways to minimise the occurrence of caries through effective preventative measures. This is where the role of fluoride comes in. In the next sections we will look at how cavities are formed, the role fluoride plays in the fight against this disease and how fluoride can be administered.

HOW DOES DENTAL CARIES FORM?

Plaque is a bacterial film on the surface of teeth formed from leftover food particles. Some organisms within the plaque, called acidogenic bacteria, produce acids as part of their metabolism when fermentable carbohydrates are digested.

These acids move through the plaque into the absorbent subsurface enamel. This process produces hydrogen ions which can dissolve the mineral, turning calcium and phosphate into a solution which is then lost from the tooth. This attack on the tooth enamel or dentin is known as demineralisation and can lead to caries if not stopped by a process known as remineralisation. We will take a closer look at both these processes later in the article.

Dental caries of the enamel normally shows up as white-spot lesions. A lesion is a small area where subsurface demineralisation has occurred and can be found beneath the top layer of dental plaque. This kind of lesion may have lost as much as 50% of its initial mineral content. It is often covered by what appears to be an undamaged surface layer, which has reformed by means of remineralisation.

HOW IS ACID PRODUCED BY BACTERIAL PLAQUE?

Fermentable carbohydrates, such as glucose, fructose, sucrose and cooked starch, can be metabolised by acidogenic bacteria to form organic acids as a by-product.

The two most important groups of bacteria that produce lactic acid are the mutans streptococci and the lactobacilli. Each group contains several species, each of which is cariogenic. Mutans

FLUORIDE AND THE CARIES BALANCE
streptococci and the lactobacilli, either separately or together, are the primary cause of dental cavities.

The process of demineralisation continues each time a person eats a carbohydrate that can be digested by bacteria.

WHAT IS FLUORIDE?

The fluoride ion (with the periodic symbol F) is the ionic form of the element fluorine and is found in great quantities in nature. The mineral is present in all food and water, which means humans ingest fluoride on a daily basis. Fluoride belongs to the halogen group of elements and is distinctive because of its exceptional relationship with mineralised tissues.

Initially, it was thought that F was beneficial when given systemically during tooth development, but later research refuted this prior assumption and proved that the topical effects of fluoride are more significant and that systemic fluoride administration can be dangerous.

Antibacterial Action

Fluoride’s antibacterial properties stem from acidification of bacterial cytoplasm when H+ and F- ions are formed from hydrogen fluoride. These ions disrupt the metabolism of bacteria by inhibiting vital enzymes, such as enolase and adenosine triphosphatase, which are needed by the organisms to function.

Other Roles

Other roles that fluoride fulfills are:
- Reduction in demineralisation of tooth enamel
- Promotion of remineralisation through the formation of fluorapatite which is more caries resistant than hydroxyapatite (Enamel)
- Forming calcium fluoride
- Reducing hypersensitivity
- Promoting osteoblast proliferation
- Encouraging firmer bone anchorage

Topical versus Systemic Fluoride

As mentioned above, fluoride is administered in two ways: topically and systemically.

Topically F is delivered through the use of biomaterials in the mouth – such as bioceramic, composite materials, glasses and the surface coatings of dental implants – as well as through sources such as toothpaste and mouth rinses.

Systemic F intake may come from sources such as water, beverages and dentifrices. It is now known that intake of unsafe quantities of fluoride may lead to toxic effects.

The symptoms of fluoride toxicity include:
- Dental fluorosis
- Skeletal fluorosis
- Muscle fibre derangement
- Headaches
- Eczema
- Impaired mental function
- Depression
- Nervousness
- Tingling in the toes and fingers
- Nausea
- Abdominal pain
- Compromised immunity
- Urinary tract complications

To prevent fluoride toxicity the United States Institute of Medicine has recommended that the daily intake of fluoride for children up to the age of 12 should not exceed 0.07 mg/kg.

Despite the dangers of ingesting too much fluoride, it is the only substance that the US Food and Drug Administration (FDA) recognises for the prevention of dental cavities.

ORAL AND DENTAL DELIVERY OF FLUORIDE

In this section we will consider the different methods of fluoride delivery and what the potential benefits and risks are.

Water Fluoridation

Water fluoridation is the most popular systemic method of fluoride delivery, since it can
conveniently and effectively deliver fluoride to a large population. During this process controlled amounts of fluoride are added to the municipal water supply. The first instance of public water fluoridation happened in 1945 in the United States of America and since then it has gained popularity across the globe.

Fluoride is a natural component of fresh water, but the concentration of the mineral varies—depending on location and the source of the water. Fluoride concentration in natural water falls within the range of 0.01 ppm to 100 ppm. Fluorosilicic acid and sodium fluoride are often used in water fluoridation.

According to the World Health Organisation’s guidelines a concentration of no more than 1.5 mg F/L (1.5 ppm) is a desirable upper limit. The US Public Health Service has recently lowered its recommendation for the optimum fluoride in drinking water to 0.7 mg/L to 1.2 mg/L. Other countries have their own standards, with concentrations set to e.g. 1 mg/L in India and 0.6 mg/L in Senegal in West Africa.

Salt Fluoridation
Salt is a necessary part of the human diet, and salt fluoridation has been used as an alternative to water fluoridation in locations without a centralised water supply. The amount of F added to salt is 90 to 350 mg/kg.

The major advantage of salt fluoridation as opposed to water fluoridation is that patients can choose if and when to use it. Since salt consumption is linked to hypertension, however, it is not desirable to be prescribed to some patients.

Milk Fluoridation
Fluoride is also added to milk on occasion. This is not a very efficient manner of delivering the mineral, since it forms complexes that cannot be dissolved, which makes it difficult to absorb.

The intake of fluoride through water, milk and salt is increasingly seen as controversial, since researchers now believe that fluoride’s ability to prevent cavities occurs after teeth emerge and that it should primarily be used in a topical way for both adults and children. Large sections of the population in developed countries are suffering from fluorosis—mottled damage of teeth and calcification of ligaments caused by excessive fluoride intake—which has led some researchers to recommend a review of water fluoridation policies.

Between 1999 and 2004 the prevalence of dental fluorosis in the USA was 41 % in adolescents between the ages of 12 and 15 years.

Miswak and Tea
A mouthwash made from Salvadora persica or miswak, obtained from the bark of a twig that contains antibacterial properties, contains approximately 1.0 µg F/g.

Tea leaves also contain high levels of fluoride. Brewed tea contains up to 6 ppm F. The fluoride from tea may interact with proteins in saliva that cling to the teeth, providing a prolonged topical effect.

Toothpaste
Fluoridated toothpaste is still the most common and cost-effective form of topical dental caries control. The detergent action of toothpaste helps patients remove plaque and food debris. Polishing the tooth surface with toothpaste also helps to prevent the build-up of micro-organisms and particles. Since toothpaste is commonly used by individuals on a daily basis, adding fluoride to its formula is a logical recommendation and one that can be easily achieved.

The first fluoride toothpaste appeared on the market in the 1970s and this is the major source of the mineral in many communities where fluoridated drinking water is not available. Fluoride is mixed into toothpastes as sodium fluoride (NaF), sodium monofluorophosphate (MFP), amine fluoride and stannous fluoride.

The benefits of fluoride in toothpaste can be impeded by factors such as:
- The concentration of fluoride
- The amount of toothpaste used
- Duration and frequency of brushing
- Rinsing behaviour

A wide range of fluoride-enriched toothpastes is available, ensuring that there is a suitable concentration for a variety of patients. The main problem with this delivery method is improper handling. The ingestion of fluoridated toothpastes can lead to serious toxic effects, which means adult supervision is essential for children using toothpaste.

When used correctly fluoridated toothpastes have 25 % more success in reducing caries than their non-fluoridated toothpastes.
Mouth Rinse

Mouthwashes can be used in conjunction with toothpaste and are recommended for patients who are specifically vulnerable to cavities.

The active compound for fluoride delivery in mouth rinses is sodium fluoride (NaF). Over-the-counter mouth rinses usually contain 0.05% NaF which is equivalent to 226 ppm of fluoride.

Mouthwash that contains fluoride has a lower viscosity than toothpastes, which means the fluoride can reach the following difficult-to-access areas:
- Interproximal regions
- Narrow pits
- Fissures

Mouth rinses which deliver fluoride are specifically recommended for:
- Children over 6 years of age with present dental cavities
- Patients who are susceptible to cavities
- Patients undergoing orthodontic treatment – to reduce the risk of demineralisation around orthodontic brackets
- Patients with impeded salivary function
- Patients with decreased physical dexterity

In order to prevent its ingestion, mouthwashes must not be prescribed to the following patients:
- Children under 6 years of age
- Mentally handicapped patients

Fluoride Varnishes

Fluoride varnishes have been used for caries prevention and control since the 1960s. Varnish must be applied by a dental hygienist or dentist.

Topical varnishes can deliver fluoride to both surface and subsurface carious lesions by the formation of deposits of calcium fluoride. These deposits provide fluoride over a long period of time. The application method is quick, straightforward and not uncomfortable for patients.

Fluoride varnishes can be used to control:
- Active caries
- Root surface caries
- Xerostomia (dry mouth)
- Hypersensitive enamel areas and dentine

Fluoride varnishes contain a high fluoride concentration (22 mg/mL, 2.2%, or 22,000 ppm), but it is considered safe and effective, since a small quantity (0.3–0.6 mL containing 6.6–13.2 mg F) is applied and the ingested amount is normally considered to be too little to induce any toxic effects. However, Feltman and Kosel found that 1% of their subjects from a group of pregnant women and children exhibited side effects from 1 mg fluoride administered orally daily, including skin rashes, gastric distress and headaches.

Fluoride Gel

Stannous fluoride gel which gives the equivalent of 970 ppm of fluoride is used to treat root surface caries. It has been built into artificial saliva to reduce caries in cancer patients who have undergone radiation therapy. This type of fluoride gel tastes bad and can cause stains.

Acidulated phosphate fluoride (APF) gels incorporate sodium carboxymethyl cellulose, a water-soluble polymer, and produces a viscous solution that is easy to apply by means of custom-made trays. This kind of gel can easily penetrate areas between teeth, but can cause discoloration and etching of dental restorations.

Neutral pH gel which offers 9000 ppm F can treat conditions such as exposed or carious dentine, hypomineralised porous enamel surfaces and dental erosions. Sodium fluoride has an acceptable taste to patients, is non-irritating and does not cause discoloration of either tooth tissue or restorations.

Restorative Dental Material

There is a selection of dental restorative materials available that can deliver fluoride. These materials restore damaged tooth tissue and act as fluoride reservoirs. Materials such as these release a fair amount of fluoride into the oral cavity and can get a recharge boost once fluoride presents itself from another source, such as toothpaste or mouthwash.
Glass ionomer cement (GIC) offers good chemical adhesion to dental hard tissues and has the capability of releasing and recharging fluoride ions. For many dental practitioners GIC is the material of choice for root caries and secondary caries. GIC offers a significant initial release of F, followed by sustained release. The ability of the restoration to recharge itself with fluoride depends upon factors such as its age, the material used and concentration and frequency of fluoride exposure.

This ability to recharge with fluoride can also be seen in resin based materials, but to a lesser extent than with GIC.

Fluoride Containing Delivery Devices
Slow fluoride releasing devices help in maintaining an increased level of fluoride in both saliva and dental plaque. Some of these devices include:

- Mucoadhesive tablets - fluoride adheres to tissue in the mouth and for the management of oral diseases can act for a longer period of time for caries protection
- Chitosan micro-particles - a co-polymer of chitin produced by partial deacetylation, which disrupts bacterial cell membranes and also has good mucoadhesive properties for intraoral retention and act as a reservoir for initial burst and sustained release of fluoride
- Elastomeric rings - fluoride-releasing biocompatible non-inflammatory polyethylene co-vinyl acetate rings that are part of fixed orthodontic treatments
- Polyhydroxy ethylmethacrylate (PHEMA) - photo polymerised PHEMA membranes loaded with sodium fluoride are available for the controlled release of fluoride in artificial saliva

It is clear from the above discussion on the variety of fluoride delivery methods that there is clear evidence to support topical, but not systemic, administration of F as beneficial in oral healthcare. It should, however, be noted that although topical fluoride can help in the fight against tooth decay, dental cavities are not caused by a fluoride deficiency in the body.

HOW DOES TOPICAL FLUORIDE COMBAT CAVITIES?

Topical fluoride assists in the fight against cavities in these three ways:

1. INHIBITS BACTERIAL METABOLISM
When the pH value in plaque is lowered by acids produced by bacteria, part of the fluoride in the plaque fluid combines with hydrogen ions to form hydrogen fluoride (HF). HF is quickly absorbed into the cell, efficiently drawing even more HF from the outside.

Once HF is inside the cell, it breaks apart again, increasing the acidity of the cell and releasing fluoride ions that get in the way of enzyme activity in bacteria, for instance: fluoride interferes with enolase, an enzyme necessary for the bacteria to digest carbohydrates. Fluoride builds up in the cell cumulatively.

2. INHIBITS DEMINERALISATION
Fluoride can be found at low levels among the enamel or dentin crystals. This fluoride sticks to these crystal surfaces and can make a clear impact in stopping the breakdown of tooth mineral because of acidity. Fluoride that acts in this way can be found in topical sources such as drinking water and fluoride products.

Fluoride that is taken in during tooth development does not offer adequate or significant cavity protection. Fluoride is indeed needed regularly throughout our lives to offer consistent protection against the formation of cavities.

3. ENHANCES REMINERALISATION
Saliva that comes into contact with plaque neutralises its acid, raising pH, which halts and reverses demineralisation. Saliva has a high concentration of calcium and phosphate, both of which supplement teeth minerals.

The partially demineralised crystal surfaces within lesions act as nucleators and allow new surface growth wherever carious lesions occur in enamel or dentin, including the roots of teeth. Fluoride boosts this remineralisation process by attracting additional calcium and phosphate ions.
As seen in our discussion, dental caries and its prevention is a complex process. It involves multiple factors, such as oral hygiene, diet, socioeconomic status and oral microbial flora. Fluoride ions released in the mouth may be anti-microbial in nature. However, estimating the required therapeutic dose to eliminate bacteria such as *S. mutans* can be challenging because of the dynamic oral environment and all the factors that need to be taken into account.

It is nevertheless clear that topical delivery of fluoride is more effective and associated with fewer risks and is an essential protective factor in maintaining balance in the oral cavity.

### PATHOLOGICAL FACTORS
- Acid-producing bacteria
- Frequent eating / drinking of fermentable carbohydrates
- Reduced salivary function

### PROTECTIVE FACTORS
- Fluoride – remineralisation with calcium and phosphate
- Anti-microbial agents
- Saliva and its protective components

### REFERENCES
## CPD Multiple Choice Questions

**Surname:** 

**Initial:** 

**Address:** 

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**Telephone:** 

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1. Which of the following micro-organisms are responsible for causing caries?  
   - a. Carbonated micro-organism  
   - b. Cariogenic bacteria  
   - c. Hydroxyapatite bacteria  
   - d. Carcinogenic micro-organisms  

2. Which of the following is not a caries causing fermentable carbohydrate?  
   - a. Glucose  
   - b. Fructose  
   - c. Cooked starch  
   - d. Protein  

3. Fermentable carbohydrates are metabolised by acidogenic bacteria into which by-product?  
   - a. Organic acids  
   - b. Fluoride  
   - c. Hydrochloric acid  
   - d. Sodium monofluorophosphate  

4. The benefits of fluoride in toothpaste cannot be affected by which of the following factors?  
   - a. The concentration of fluoride  
   - b. The amount of toothpaste used  
   - c. The flavour of the toothpaste used  
   - d. Duration of brushing  

5. When used correctly fluoridated toothpaste has which percentage higher success rate than non-fluoridated toothpaste?  
   - a. 60 %  
   - b. 10 %  
   - c. 94 %  
   - d. 25 %  

6. Which one of the following symptoms is not commonly associated with fluoride toxicity?  
   - a. Dental fluorosis  
   - b. Headaches  
   - c. Blindness  
   - d. Nausea  

7. Which of the following is a topical delivery method of fluoride?  
   - a. Water fluoridation  
   - b. Mouth rinse  
   - c. Milk fluoridation  
   - d. Salt fluoridation  

8. Which of the following is the most common systemic delivery method of fluoride?  
   - a. Milk fluoridation  
   - b. Tea  
   - c. Water fluoridation  
   - d. Fluoride gel  

9. Which of the following is not a Fluoride Containing Delivery Device?  
   - a. Mucoadhesive tablets  
   - b. Glass ionomer cement  
   - c. Elastomeric rings  
   - d. Polyhydroxy ethylmethacrylate  

10. Which of the following conditions do fluoride varnishes not control?  
    - a. Excessive plaque on the tongue  
    - b. Active caries  
    - c. Root surface caries  
    - d. Hypersensitive enamel and dentine  

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This is to state that I have participated in the CPD-approved programme and that these are my own answers.  

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Signature  

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Date
11. Fluoride combats cavities in three ways. Which one of the following is not one of those ways?
   - a. Inhibits bacterial metabolism
   - b. Enhances bacterial metabolism
   - c. Inhibits demineralisation
   - d. Enhances remineralisation

12. Saliva that comes into contact with plaque has the following effect:
   - a. It encourages demineralisation
   - b. It breaks down new surface growth
   - c. It destroys calcium
   - d. It neutralises its acid

13. Which of the following is a pathological factor of the cavity balance?
   - a. Remineralisation
   - b. Acid-producing bacteria
   - c. Antibacterial agents
   - d. Saliva and its protective components

14. Which of the following is a protective factor of the cavity balance?
   - a. Acid-producing bacteria
   - b. Drinking of fermentable carbohydrates
   - c. Fluoride remineralisation with calcium & phosphate
   - d. Reduced saliva flow and function

15. Which type of bacteria is largely responsible for cavities?
   - a. Salmonella enteritidis
   - b. Helicobacter pylori
   - c. Mutans streptococci
   - d. Escherichia coli

16. Which of the following facts about fluoride is not true?
   - a. Fluoride is not naturally found in water
   - b. Fluoride's symbol is $\text{F}^-$
   - c. Fluoride is the ionic form of the element fluorine
   - d. Fluoride belongs to the halogen group of elements

17. Aside from cavity protection fluoride fulfils other roles. Which of the following is not one of those roles?
   - a. Promoting osteoporosis
   - b. Forming calcium fluoride
   - c. Reducing hypersensitivity
   - d. Encouraging firmer bone anchorage

18. Fluoride mouth rinses are not recommended for:
   - a. Patients who are susceptible to cavities
   - b. Children under 6 years of age
   - c. Patients with impeded salivary function
   - d. Children under 12 years of age

19. Which of the following is true about miswak?
   - a. Its leaf sap contains antimicrobial properties
   - b. It is a kind of green tea
   - c. It contains approximately 15.0 $\mu$g F/g
   - d. It is made from Salvadora persica

20. Which of the following is not one of the hard-to-reach areas that benefit from mouthwash that contains fluoride?
   - a. Interproximal regions
   - b. Narrow pits
   - c. Salivary glands
   - d. Fissures

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Signature

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Date