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Topical versus systemic fluoride: which is more effective in preventing dental caries in high risk population?

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Thesis

TOPICAL VERSUS SYSTEMIC FLUORIDE:
WHICH IS MORE EFFECTIVE IN PREVENTING DENTAL CARIES
IN HIGH RISK POPULATIONS?

by

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B.S., University of California, San Diego, 2007

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TOPICAL VERSES SYSTEMIC FLUORIDE:
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Boston University School of Medicine, 2013

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ABSTRACT

Dental caries is a multifactorial, bacterial, chronic infection that affects millions of people in the world and has become a public health problem. Also referred to as tooth decay, this disease is one of the most common disorders throughout the world, second only to the common cold. Dental caries is the most common chronic childhood disease in the United States and is 5 to 7 times more common than asthma. According to the World Oral Health Report in 2003, dental caries affect 60-80% of school children and a vast majority of adults.

Dental caries is a chronic bacterial infection of the hard tissue of the tooth that is characterized by alternating phases of demineralization and remineralization. Dental decay can lead to significant pain and dysfunction that can interfere with basic functions such as eating, sleeping, and speaking. If left untreated, dental caries can result in cavities forming and eventually tooth loss. Although the prevalence and severity of dental caries has decreased over the years, this disease can be better controlled with proper fluoride exposure.

Fluoride therapy has become the cornerstone strategy in the prevention of dental
caries development and progression. With fluoride being available in various forms, fluoride exposure and/or treatment has greatly increased and has led to decreased incidences of dental caries. Fluoride has the ability to control the initiation and progression of carious lesions, mainly through the promotion of remineralization and the reduction in tooth enamel demineralization. Whether administered systemically or topically, the use of fluoride has proven to be effective in reducing the prevalence of dental caries.

The aim of this review is to compare the topical methods of fluoride therapy with systemic applications. The goal is to evaluate the various forms of fluoride treatments based on cost effectiveness, safety, concentration and dosage of fluoride, ease of application, and accessibility to the community. This review will also identify the populations that are most susceptible to dental caries. The purpose of this review is to examine the benefits and risks of the various options of fluoride treatments in order to determine which would be the most the effective, safe, and efficient means of preventing dental caries in high risk populations.

Based on the literature review, it was determined that the populations with the greatest risk for dental caries comprised of young children who were from lower socioeconomic backgrounds and elderly adults over the age of 65. After comparing the various forms of fluoride therapies, it was found that systemic fluoride treatments, mainly water fluoridation, would be the most effective in preventing dental caries in high caries risk populations.
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<tr>
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<td></td>
</tr>
<tr>
<td>ASTDD</td>
<td>American Association of State and Territorial Dental Directors</td>
<td></td>
</tr>
<tr>
<td>CDC</td>
<td>Center for Disease Control and Prevention</td>
<td></td>
</tr>
<tr>
<td>DMFT</td>
<td>decayed, missed, and filled permanent teeth</td>
<td></td>
</tr>
<tr>
<td>EPS</td>
<td>extracellular polysaccharides</td>
<td></td>
</tr>
<tr>
<td>FMR</td>
<td>fluoride mouth rinse</td>
<td></td>
</tr>
<tr>
<td>NaF</td>
<td>sodium fluoride</td>
<td></td>
</tr>
<tr>
<td>Ppm</td>
<td>parts per million</td>
<td></td>
</tr>
<tr>
<td>SES</td>
<td>socio-economic status</td>
<td></td>
</tr>
<tr>
<td>S. mutans</td>
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</tr>
<tr>
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<td></td>
</tr>
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<td>USPHS</td>
<td>United States Public Health Service</td>
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INTRODUCTION

Although dental caries is largely preventable, it remains one the most common chronic diseases throughout the world. Dental caries is ubiquitous and can affect anyone throughout his/her lifetime. It is a primary cause for oral pain and tooth loss. The presence of dental caries is a public health problem for both developing and developed countries.

Dental caries, also commonly known as tooth decay, is an infection that occurs when cariogenic bacteria colonize the tooth surface in the presence of dietary carbohydrates, especially refined sugars. The bacteria metabolize the carbohydrates, producing acids, which over time demineralizes the tooth structure. In its early stages, caries are reversible, but if no action is taken to remedy the damage, demineralization of the tooth will continue until a cavity, or hole in the tooth, will develop. Eventually without proper care, caries can progress until the tooth is destroyed and lost. Fortunately, dental caries is a disease that progresses slowly, therefore, with the proper preventive measures, costly dental treatments can be avoided.

The risk of developing dental caries varies and is dependent on many risk factors. Risk for caries can include physical, biological, environmental, and behavioral factors, such as poor dietary habits, gingival recession, genetics, reduced salivary flow, low fluoride exposure, lower socioeconomic status, and developmental disabilities (Yip, 2012). Besides these various risk factors, dental caries is also age related. Its prevalence is highest in children with a high sugar intake and poor oral hygiene, as well as older
adults who have exposed root surfaces (Yip, 2012).

Progression of dental caries can result in a myriad of adverse effects, including pain, reduced sleep, a decreased ability to eat certain foods, and lowered self-esteem. Besides physical pain and functional impairment, dental caries also incurs costly treatments. The burden of dental caries lasts a lifetime because once the tooth structure has been destroyed; it will need extensive restorations and maintenance throughout life. As people are living longer and retention of teeth has increased, it has become even more important to take the proper preventive measures in order to limit the incidence of dental caries.

Fluoride plays a significant factor in preventing dental caries (Van Loveren, 1990). Fluoride has the ability to slow or reverse the progression of caries by enhancing remineralization and inhibiting demineralization of tooth enamel, which is caused by cariogenic bacteria in the oral cavity. It is most effective in preventing caries formation when a constant low level of fluoride is maintained in the oral cavity. After prolonged exposure, fluoride becomes available in plaque, saliva, and the tooth’s outer layer, where it can increase resistance to acid attacks, serve as a reservoir for remineralization of small carious lesions, and act as a bacterial inhibitor (Van Loveren, 1990).

Fluoride can be used both topically and systemically in order to prevent caries formation. Systemically, ingested fluoride can be incorporated into tooth enamel before teeth have even erupted and thus making the tooth surfaces more resistant to caries formation (Jones, 2005). The most common forms of systemic fluoride therapy include water fluoridation and dietary supplements. On the other hand, fluoride also possesses
topical action through direct application to erupted dentition. In this case, fluoride promotes remineralization of damaged tooth enamel (Jones, 2005). Topical applications include fluoride toothpaste, mouthrinses, varnishes, gels and foams.
LITERATURE REVIEW

**DENTAL CARIES**

Dental caries, also known as tooth decay or cavities, is one of the most common diseases in the world. Caries usually occur in children, teenagers, and the elderly, but it can affect any person with teeth. Dental decay is a complex process that is caused from a combination of plaque, bacteria, and food. Without proper oral hygiene and regular visits to the dentist, tooth decay can develop into small holes, otherwise known as cavities, over an extended period of time. Cavities are largely preventable, but if left untreated can grow larger and affect nerves, cause tooth fractures, lead to tooth abscess, and ultimately tooth loss (Medline, 2012).

*Pathogenesis*

The oral microbiota serves as a host defense of the body by acting as a barrier to exogenous organisms. Within the oral cavity is a large and diverse group of bacterial microbes, which are usually harmless, but under certain conditions can cause oral infections, such as dental caries.

The tooth surface is covered with a biofilm, or slime layer consisting of millions of bacterial cells, saliva, and food debris (Forssten, 2010). If not cleaned properly and regularly, this biofilm on the teeth thickens and develops into a sticky mass called plaque. Plaque provides an adhesion site for the colonization and growth of various bacterial species.
Formation of dental plaque typically follows a three step process that can take days to weeks to develop. First, the enamel of teeth is coated by salivary glycoproteins and bacteria thus creating a dental pellicle layer (Forssten, 2010). This thin layer on the surface of the enamel also contains acidic proline-rich proteins that allow bacterial adhesion. The second step involves the interaction of bacteria in the oral cavity with the pellicle on the enamel of the teeth. Primary colonizers, such as *Streptococcus (S) sanguis*, *Actinomyces vicosus*, *Streptococcus mitis*, and *Streptococcus gordonii*, are the first bacteria to attach to the pellicle glycoproteins via specific cell to surface interactions and form micro colonies. During the third step, bacterial species, such as *Streptococcus mutans*, *Lactobacillus*, and *Streptococcus sobrinus*, attach to these primary colonizers and grow in these colonies (Forssten, 2010).

Certain bacteria, including *S. mutans*, thrive on food and drinks that are high in fermentable carbohydrates, such as glucose, fructose, and particularly sucrose (table sugar). The level of *S. mutans* colonization within the plaque increases through higher sucrose consumption (Tanzer, 2001). *S. mutans* has a central role in the etiology of dental caries because it can attach to the enamel salivary pellicle and other plaque bacteria. *S. mutans*, as well as *Lactobacilli* and *S. sobrinus*, produces strong organic acids from dietary sugars that foster an environment that is at a higher risk for dental caries. *S. mutans* produces a bacterial enzyme, known as glucosyltransferase, which converts sucrose into extracellular polysaccharides (EPS) (Tanzer, 2001). Sucrose is considered to be the most cariogenic carbohydrate in a person’s diet because it is the only dietary carbohydrate that can be converted into EPS (Peterson, 2011). The EPS produced
from sucrose, fosters *S. mutans’* attachment to teeth and also allows other bacteria to attach to the primary colonies.

Besides being converted to EPS in the plaque, sucrose can also be fermented to acidic end products. If not removed from the teeth, plaque develops and thickens over time and as a result, oxygen can no longer diffuse into the bacterial colonies. At this point, facultative anaerobes, such as *S. mutans, Lactobacilli, and S. sobrinus*, colonize the plaque and break down sucrose and produces a number of fermentation products (lactate, acetate, pyruvate, and formate) that can contribute to creating a highly acidic environment in the oral cavity (Marsh, 2010). If the production of acid exceeds the buffering capacity of saliva to neutralize acidic metabolic products, it results in the reduction of dental plaque pH (Marsh, 2010). It is at this point where dental caries is initiated.

Organic acids, such as lactic acid, are released from the acidified plaque, which lead to the demineralization of hydroxylapatite crystals in the enamel of teeth and ultimately leads to dental caries (Peterson, 2011). Even though enamel is the hardest tissue in the human body due to its high mineral content, over time the acids from the bacteria can cause tiny openings or holes in the enamel. A thickened buildup of plaque also will not allow saliva to penetrate and neutralize the acids that are being produced by the bacteria (Tanzer, 2011). Saliva acts as one of the mouth’s natural defenses and can promote remineralization of tooth enamel. Eventually, the caries continues until the invading bacteria physically penetrate the softer and less resistant dentin of the tooth (Peterson, 2011). As the dentin is slowly destroyed by the tooth decay, it can no longer
support the enamel, which becomes brittles and easily breaks from the tooth (Peterson, 2011). This becomes critical because the body has no way of regenerating enamel.

If the extent of tooth decay continues, the cementum, which is the hard tissue that covers the roots of the teeth, can be affected. As can be seen in Figure 1, the roots of teeth have a very thin layer of cementum over a very thick layer of dentin, thus caries that affects cementum also affects dentin. Because the cementum covering the roots of the teeth is not as durable as enamel, root caries progress much faster (Peterson, 2011). If tooth decay still persists, bacteria can then enter the pulp, which contains nerves and blood vessels (Figure 1). At this extent, the bone supporting the tooth can be comprised and tooth loss can occur. Otherwise, an untreated cavity can also lead to a tooth abscess due to the bacterial infection (Tanzer, 2005).

Figure 1: Structure of teeth. Retrieved from Cochrane Oral Health Group at http://ohg.cochrane.org/dental-diagrams-and-figures
Risk Factors

Dental caries is a multifactorial disease that involves the host, microorganisms, and a multitude of other determinants. Variables that can be attributed to caries development include behavioral, biological, or environmental factors.

Behavioral factors that can increase risk for developing caries include diets high in sugars and poor oral hygiene. According to the World Health Organization (WHO), the frequent consumption of simple carbohydrates, primarily dietary sugars, is associated with an increased incidence of dental caries (WHO, 2003). Foods and drinks, such as ice cream, honey, cookies, cake, soda, hard candy, and chips, are more likely to cause decay due to their high sugar content, specifically sucrose (Mobley, 2003). In addition, many of these foods will stick to teeth, which will make it more difficult for saliva to wash them away. Frequently snacking on sugary foods or sipping on sodas leads to quicker progression towards dental caries because the bacteria in dental plaque is constantly being supplied with dietary sugars that can be metabolized into acidic by-products, which cause demineralization of tooth enamel (Mobley, 2003).

Besides dietary habits, oral hygiene practice is a vital factor in determining dental caries prevalence. Inadequate tooth brushing can lead to a higher incidence of dental caries. Without frequent teeth cleaning after eating and drinking, plaque quickly builds and the first stages of tooth decay can begin (Yip, 2012). Not flossing regularly is also a risk factor because food debris can become lodged between teeth, which will develop into plaque and tartar, eventually progressing to dental caries (Yip, 2012). Another oral hygiene risk factor is inconsistent visits to the dentist for professional cleanings and oral
examinations. Overall, poor oral hygiene is one of the most common risk factors that increase the occurrence of dental caries.

Biological factors that can put someone at a higher risk for developing dental caries include tooth anatomy and location, as well as reduced saliva. Teeth in the back of the oral cavity, such as the premolars and molars, are more susceptible to tooth decay due to their frequent use for grinding and chewing food (Mobley, 2009). Food debris can easily become embedded in posterior teeth and due to their location; they are less accessible for a tooth brush or floss to clean. Unfortunately, some people naturally have teeth with deeper grooves. For this group, it is easier for food particles to be forced into these deeper pits and fissures on their chewing surface of their teeth. Another tooth site that can be a risk factor for dental caries is an exposed root surface. This allows bacteria access to the tooth’s cementum and dentin, which are more susceptible to dental decay than enamel (Petersen, 2005). Finally, xerostomia, more commonly referred to as dry mouth, and hyposalivation, reduced saliva secretion, are linked with increased dental caries because of saliva’s role in washing food and plaque away from teeth (Tanzer, 2005). Additionally, saliva contains the buffering capacity to neutralize the acidic environment created by the bacteria in dental plaque (Tanzer, 2005). With a reduced saliva flow, decay can develop on tooth surfaces that would usually not be susceptible to caries.

Environmental factors that could impact dental caries prevalence include socioeconomic status, culture, and special health care needs. Among the possible environmental risk factors for dental caries, socioeconomic status (SES) is at the top of
the list. Low SES is regarded as a caries risk factor that is just as important as high sugar consumption and poor oral hygiene (Yip, 2012). SES generally factors in a person’s education level, income, and place of residence. Low socioeconomic status can limit a person’s access to oral health services. Whether due to living in a rural area or not having the financial capacity to see the dentist for regular checkups and receiving proper dental treatments, people at a socioeconomic disadvantage suffer a greater incidence of dental caries (Yip, 2012). Additionally, those at a lower SES may lack access to healthy diet choices and proper oral health education. These factors contribute to the development of dental caries, due to the consumption of food and drinks high in sugar combined with insufficient oral hygiene instruction.

Besides SES, cultural barriers can be an environmental factor that contributes to dental caries. Refugees are a particular group that is susceptible to developing dental caries. Refugees can be defined as people who are outside their native country and cannot return because of fear of persecution because of race, religion, nationality, or political opinion (Cote, 2004). Many refugees originate from areas where diagnosis and treatment of oral diseases, such as dental caries, are lacking and war or civil unrest has disrupted the healthcare system (Cote, 2004). These refugees also have vastly different oral health care beliefs, as well as cultural and linguistic barriers, which increase the likelihood of caries.

Finally, people with special care needs can see an increased incidence of dental caries. Because these special needs patients may already be dealing with developmental, mental, emotional, behavioral, or physical disabilities, oral health may not be regarded as
a priority (Glassman, 2003). Furthermore, these patients are better suited to see dental practitioners who have experience working with special care needs patients. Because there are fewer dental health professionals specializing in this field, it may be more difficult for the patients to find oral health services that are handicap accessible (Glassman, 2003). Besides accessibility and high treatment cost at specialized facilities, many special needs patients are unable to maintain proper oral hygiene, such as brushing and flossing, without assistance. All these factors contribute to a higher caries risk.

Besides these behavioral, biological, and environmental factors, incidence of dental caries can be greater within specific age groups. Dental caries can be classified into low, moderate, or high categories as shown in Table 1. The two age groups that are at the highest risk for developing dental caries include young children and the elderly.
The elderly population, consisting of people who are above 65 years of age, continues to grow worldwide. With increased life expectancy, the elderly today retain more or all of their natural teeth than did previous generations (Petersen, 2005). Because this aging population is keeping their teeth longer, there has been an elevated incidence of dental caries (Petersen, 2005). Due to wear and tear over time, many seniors
experience gingival recession and bone loss, which expose root surfaces (Petersen, 2005). This root exposure accounts for the high incidence of root caries in the elderly population. In addition, many elderly adults have had multiple dental restorative work, including fillings, crowns, bridges, and dentures. Over time these restorations break down and can no longer effectively help preserve tooth structure, thus leading to the progression of tooth decay.

The high incidence of dental caries not only occurs in the elderly population, but in young children as well. The primary culprit for children being at a greater risk for caries is diet. Because most children have an affinity for candy, cookies, cake and soda, frequent consumption of these foods high in sugar put this group at an increased risk for tooth decay. Specifically, infants can develop caries through frequent sipping of drinks with high sugar content from baby bottle feeding (Bader, 2004). Besides dietary habits, lack of proper oral hygiene and dental education can attribute for dental caries being the most common childhood chronic disease (Bader, 2004).

**Treatment**

Treatment of cavities can preserve tooth structure and prevent further destruction. Early treatment can be less painful and less expensive than treatment of extensive decay. Depending on the severity of the tooth decay, several treatment options may be offered, including fillings, crowns, root canals, topical fluoride, and extractions.

At the earliest stages of damage, small carious lesions can be cured with professional fluoride treatment (Yip, 2012). As the cavity is just forming, fluoride
treatments can help remineralize the tooth’s enamel and prevent the progression of tooth decay. For larger carious lesions, dentists can perform fillings to replace decayed areas of teeth. Fillings, which are also referred to as restorations, can be composed of various materials, including tooth colored composite resins, porcelain, gold, and silver amalgam. Porcelain and composite resins more naturally match tooth appearance, therefore, are usually chosen for anterior teeth for aesthetic purposes. On the other hand, gold and amalgam are considered to be stronger, therefore these materials are more suitable for the posterior teeth, where chewing and grinding occurs more often (Yip, 2012).

If tooth decay becomes extensive, there may be limited tooth structure remaining, which would not allow a filling to be placed in the tooth. A large filling put into a weakened tooth can cause the tooth to fracture (Yip, 2012). At this point, a crown would be the recommended treatment in order to restore the tooth. Crowns, or caps, are fitted over the remainder of the tooth after all decayed and weakened areas are removed and restored (Yip, 2012). Crowns are often made of gold, porcelain, or porcelain attached to metal (Yip, 2012).

If decay reaches the pulp of the tooth and kills the nerves and vascular tissue, a root canal is necessary to preserve the tooth (Yip, 2012). The infected tooth pulp is removed, along with decayed areas of the tooth. The roots of the tooth are cleaned then filled with a sealing material called gutta percha (Yip, 2012). The tooth can now be filled and a crown can be placed on top.
In certain cases of dental caries, teeth can become so severely decayed that they cannot be effectively restored. For this situation, extractions serve as the treatment option.

**Prevention**

Due to the high costs of dental care, it is best to take preventative measures in order to avoid the development of dental caries. Even though dental restorations can help preserve and repair damaged tooth structure, these restorations, which include fillings, crowns, or root canals, will eventually break down and additional dental work will be needed. Therefore, the most health conscious, cost effective and least painful solution is to practice good oral and dental hygiene in order to keep the natural teeth intact. Regular oral exams with the dentist can help detect caries in the early stages. More importantly, good personal hygiene, consisting of brushing at least twice a day, flossing daily, and receiving professional cleanings every 6 months, can prevent the onset of caries formation (Lewis, 1995). The purpose of oral hygiene is to remove food particles left on teeth, which can lead to carbohydrate fueled acid demineralization. By limiting the amount of bacteria and sugar adhered to teeth and preventing the formation of bacterial plaque, teeth are less likely to develop dental caries.

Besides oral hygiene, eating a diet low in sugar content and avoiding frequent snacking or sipping of sugary foods and drinks can serve as effective preventive measures to lower the risk of developing cavities and tooth decay. Frequently eating or drinking of these items supply the bacteria with a constant source of sugars and
carbohydrates that can be produced into acids, which can demineralize tooth enamel, dentin, and cementum (Moynihan, 2004). In addition to minimizing snacking throughout the day, avoiding sticky, chewy, and sugary foods can help prevent tooth decay. Chips or candy can become stuck in grooves and pits of teeth for long periods and may not be easily removed by a toothbrush or floss and can develop into plaque over time. By taking these preventive measures, teeth will not be under constant attack and dental caries is less likely to occur.

The use of dental sealants is another means of prevention. Sealants are thin protective plastic coatings that are applied to chewing surfaces of the molars in order to prevent food from being trapped in the grooves, pits, and fissures of teeth (Moynihan, 2004). Sealants can last up to 10 years before needing to be replaced (Moynihan, 2004). The coating can help prevent the formation of cavities by inhibiting the accumulation of bacterial plaque on the teeth.

Fluoride treatment is offered in various forms and can be effective in protecting against dental caries. It has been documented that people who ingest fluoride in their drinking water or by fluoride supplements have fewer dental caries (Nikiforuk, 1988). Fluoridated toothpastes and mouthwashes can help protect the surface of the teeth and make them resistant to decay. For professional applications, dentists can administer concentrated fluoride onto teeth through the use of fluoride varnish, gels, or foams. Fluoride is able to prevent caries through remineralization of enamel on tooth surfaces.
FLUORIDE

Over the years, it has been demonstrated that fluoride plays a major role in the reduction of caries incidence and prevalence. Fluorides are naturally found throughout the world and are present to some extent in all plants, food, but in varying concentrations (Nikiforuk, 1988). Fluorine, the element from which fluoride is derived, is released into the environmentally naturally both in air and water (Nikiforuk, 1988). The wide availability of fluorides from various sources has improved overall oral health, but the total daily intake of fluoride must be carefully monitored in order to achieve safe and effective preventive measures in reducing the incidence of tooth decay (Table 2). Frequent exposure to small amounts of fluoride has been shown to reduce the risk of dental caries through its protective mechanisms, including remineralization of tooth enamel and altering of bacterial metabolism in the oral cavity (Nikiforuk, 1988).


<table>
<thead>
<tr>
<th>Age Group</th>
<th>Reference Weights kg (lbs)*</th>
<th>Adequate Intake (mg/day)</th>
<th>Tolerable Upper Intake (mg/day)</th>
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<tr>
<td>Infants 0-6 months</td>
<td>7 (16)</td>
<td>0.01</td>
<td>0.7</td>
</tr>
<tr>
<td>Infants 7-12 months</td>
<td>9 (20)</td>
<td>0.5</td>
<td>0.9</td>
</tr>
<tr>
<td>Children 1-3 years</td>
<td>13 (29)</td>
<td>0.7</td>
<td>1.3</td>
</tr>
<tr>
<td>Children 4-8 years</td>
<td>22 (48)</td>
<td>1.0</td>
<td>2.2</td>
</tr>
<tr>
<td>Children 9-13 years</td>
<td>40 (88)</td>
<td>2.0</td>
<td>10.0</td>
</tr>
<tr>
<td>Boys 14-18 years</td>
<td>64 (142)</td>
<td>3.0</td>
<td>10.0</td>
</tr>
<tr>
<td>Girls 14-18 years</td>
<td>67 (125)</td>
<td>3.0</td>
<td>10.0</td>
</tr>
<tr>
<td>Males 19 years and over</td>
<td>76 (166)</td>
<td>4.0</td>
<td>10.0</td>
</tr>
<tr>
<td>Females 19 years and over</td>
<td>61 (133)</td>
<td>3.0</td>
<td>10.0</td>
</tr>
</tbody>
</table>
Composition

The fluoride ion (F\textsuperscript{-}) is derived from the reduced form of the element fluorine (Featherstone, 1999). Fluorine is a halogen and very reactive gas that is not found in free elemental form in nature (Featherstone, 1999). Thus, fluorine exists only in combination with other elements as a fluoride compound. Many fluoride minerals can be found in rocks and soils and are widely distributed in the earth’s crust (Featherstone, 1999). Water will pass over these land masses and rocks and dissolve these fluoride compounds, releasing fluoride ions. The result is that small amounts of fluoride can be found in springs, streams, lakes, rivers, sea water, and plants (Featherstone, 1999). Plants, in particular, tend to absorb fluoride through the soil. As for food, canned fish tend to contain the highest amounts of fluoride (Featherstone, 1999). This can be attributed to these fish living in waters rich in fluoride. Fluoride’s ubiquitous presence in nature makes it an inevitable component of the human diet.

Fluoride absorption depends on its solubility, degree of ionization, concentration, and amount of fluoride ingested, as well as dietary components, such as calcium, which can form insoluble salts with fluoride (Nikiforuk, 1988). Under normal dietary conditions, about 80\% of fluoride consumed is absorbed, while less soluble fluorides will result in only 30-50\% absorption (Nikiforuk, 1988). Fluoride is primarily deposited in hard tissues and becomes incorporated into hydroxyapatite crystals of the skeleton (Nikiforuk, 1988).
Mechanism of Action on Teeth

Tooth enamel is primarily composed of a phosphate and calcium compound referred to as hydroxyapatite (Van Loveren, 1990). This calcium phosphate mineral begins to dissolve when exposed to an environment at sufficiently low pH (~5 or less) (Van Loveren, 1990). Bacteria that thrive on the sugars found in the oral cavity can accumulate and produce acids, which cause demineralization of tooth enamel. If this exposure to acids is present for several weeks or months, early stages of dental caries can form. The oral cavity combats this through saliva. Saliva is able to neutralize the acid, which allows the teeth to remineralize enamel. As long as the rate of demineralization and remineralization remain in balance, teeth will remain strong and healthy (Van Loveren, 1990).

When more minerals are lost from teeth than are replaced, dental caries and cavities can develop (Van Loveren, 1990). Fortunately, fluoride has the capability to slow or prevent dental caries. Fluoride is able to do so through three different mechanisms. First, fluoride inhibits demineralization of enamel. This effect is due to fluoride’s incorporation into the hydroxyapatite crystals of enamel, resulting in fortified enamel that is less susceptible to acid erosion (Van Loveren, 1990) (Figure 2). Second, fluoride promotes the remineralization of damaged enamel. Fluoride increases the concentration of calcium in plaque fluid and triggers the formation of calcium-phosphate fluoride salt, which precipitates onto enamel on the teeth’s surface (Figure 2). This promotes a more stable crystal structure in the enamel that is more caries resistant. Finally, in concentrated forms, such as varnishes or gel and foams, fluoride can inhibit
the growth of bacteria on teeth. If the fluoride concentration in dental plaque is high enough, it can result in the reduction of bacterial enzymes responsible for producing acids from fermentable sugars (Van Loveren, 1990). It has been shown that when enolase, a bacterial enzyme in the oral cavity, is inhibited, lactic acid production is. In addition to interfering with enzyme activity, high concentrations of fluoride can inhibit the phosphotransferase system, which facilitates the transport of sugars into cells (Van Loveren, 1990). By decreasing the amount of sugar in the oral cavity, fluoride is depriving the bacteria of its food source, thus reducing acid production.

Figure 2: Remineralization in the presence of fluoride. Taken from Cury, 2008.
**FLUORIDE THERAPY**

Fluoride can be delivered either topically or systemically in order to protect teeth and prevent tooth decay and cavities. Fluoride therapy ranges from at home therapies to professional administered to community based. Fluoride treatment is most effective when used as a preventive measure. At the earliest stages of the caries process, before a cavity forms, fluoride can reverse small carious lesions (Ijaz, 2010). Once a cavity has developed, fluoride can no longer arrest the caries process, but can only slow it down (Ijaz, 2010).

**Topical Fluoride**

Topical fluorides are delivered to exposed surfaces of the dentition, at elevated concentrations for a local protective effect in making the teeth more resistant to decay. Topical fluorides are applied to the teeth directly and are most effective when delivered at very low doses several times a day (Ijaz, 2010). Topical treatments can be divided into self-applied and professionally applied fluorides. Self-applied therapy includes toothpastes and mouthrinses, while fluoride gels, foams, and varnishes are typically applied to teeth by a dental professional.

**Fluoride Varnish**

Fluoride varnish is a small highly concentrated dose of fluoride that can be applied professionally by dentists, dental hygienists, or a certified health professional. The aim of varnishes is to prolong the contact between fluoride and the tooth enamel and
promote the remineralization of damaged enamel.

Fluoride varnish application can be used for children or adults. Fluoride varnish generally is composed of a concentrated fluoride (22,600 ppm) combined with a resin or synthetic based solution (Azarpazhooh, 2008). The entire dentition can be treated with a small amount of varnish, with as little as 0.3-0.6 ml (Azarpazhooh, 2008). The application of varnish is not intended to adhere permanently to a tooth, but should remain in contact with the surface for several hours. Tooth brushing or wiping or drying with cotton rolls or gauze is adequate to clean the teeth before varnish application. The varnish is then applied with a microapplicator, or a fine brush, to surfaces of the teeth where caries is most likely to initiate. Even with slight moisture in the oral cavity, the varnish will quickly set on contact with teeth. Afterwards, patients are advised to avoid brushing or flossing until the next day. For the first four hours after applications, patients are recommended to only drink water and eat soft foods (Azarpazhooh, 2008).

Varnish offers advantages in that it is easy to apply, has a quick base setting, and a slow release of fluoride over time. Furthermore, only a relatively small amount of fluoride varnish is required for the whole dentition. Due to small amounts of fluoride used and a quick setting time, only a negligible amount of fluoride is ingested. Fluoride varnish is an ideal option to treat populations that lack access to oral health care. With little equipment required for fluoride varnish application, it can be used outside a dental setting and in various locations.

Generally varnishes are applied every 6 months, but in groups with high caries risk it can be administered every 3 months (Weintraub, 2006). Varnishes tend to be more
effective when they are applied to teeth earlier in life. Infants generally get their first teeth in at 6 months and at this point, fluoride varnish can be applied to strengthen the primary dentition (Weintraub, 2006). Once all the permanent teeth have come in, fluoride varnish can again be applied to help prevent tooth decay. In addition, varnishes are a non-invasive procedure that creates less patient discomfort and is a good option for patients with strong gag reflexes. Furthermore, varnish comes in a variety of flavors, which can be beneficial when dealing with a younger population.

According to the American Dental Association (ADA), two or more applications of fluoride varnish per year are effective in reducing caries prevalence in high risk populations (ADA, 2006). Fluoride varnish is a simple and easy preventive measure that can help avoid costly dental procedures, such as fillings, root canals, crowns, or implants.

**Toothpaste**

Since being introduced in the late 1960s, fluoridated toothpaste has been the single factor most responsible for the reduction of dental caries in many countries (Jones, 2005). Fluoridated toothpaste has been shown to reduce the percentage of decayed, missing, and filled teeth (DMFT) by 23% (Jones, 2005).

Tooth brushing with fluoridated toothpaste is by far the most common form of caries prevention (Marinho, 2003). Toothpaste is a paste or gel dentifrice that is composed of water, abrasives, humectants, detergents, flavoring agents, antibacterial agents, and most important fluoride. Abrasives, which include calcium carbonate, dehydrated silica gels, hydrated aluminum oxides, magnesium carbonate, phosphate salts
and silicates, are incorporated to remove food debris, plaque, and surface stains from teeth (Marinho, 2003). Another toothpaste ingredient is humectants, which include glycerol, xylitol, and sorbitol. Humectants are agents that prevent water loss in toothpaste and reduce the tendency of toothpaste to dry into a powder. Additionally, detergents in the toothpaste create a foaming action that helps with even toothpaste distribution, which improves cleansing power. These include sodium lauryl sulfate and sodium N-Lauryl sarcosinate. In order to encourage the use of toothpaste, flavoring agents, such as saccharin, are included in toothpaste for taste. These flavoring agents come in a variety of colors and flavors. Even though these flavoring agents are sweeteners, they do not promote tooth decay (Marinho, 2003). Understandably, antibacterial agents, such as Triclosan and zinc chloride, are also common ingredients in toothpaste. Their role is to prevent buildup of hardened plaque, also referred to as tartar. In addition these antibacterial agents can help reduce bad breath and gingivitis, a mild inflammation of gum tissue. Besides these ingredients, some toothpaste can consist of potassium nitrate or strontium chloride which helps in reducing tooth sensitivity.

Fluoride is the active ingredient that is most responsible for preventing the formation of caries. Fluoride helps to strengthen tooth enamel and remineralize tooth decay. The usual concentration of fluoride in toothpaste is 1100 parts per million (ppm). There are toothpastes that are available with higher (1500 ppm F) and lower fluoride levels (500 ppm F) (Marinho, 2003). Fluoridated toothpastes contain a low enough amount of fluoride that if ingested will not be toxic and cause harm.

Toothpaste is essential in daily oral hygiene and improves the mechanical
brushing and cleaning power of a toothbrush. Toothpastes are by far the most widely used form of fluoride (Marinho, 2003). Fluoridated toothpaste is generally considered the method of choice for avoiding caries formation due to its convenient use at home. The frequency of toothpaste use, varying fluoride concentrations, and rinsing method after tooth brushing strongly influences the effectiveness of fluoride toothpastes in preventing caries.

**Mouthrinses**

Fluoride mouthrinses have been used extensively for the past 30 years to prevent dental caries. The generally advocated procedure is rinsing the mouth daily with 10 mL of a 0.05 sodium fluoride (NaF) (230 ppm F) solution or weekly with a solution containing 0.2% sodium fluoride (900-1200 ppm F) (Twetman, 2004). According to the ADA, the sequence in which you brush, floss, and rinse makes no difference as long as you do a thorough job. The use of mouthwash alone does not eliminate the need for brushing and flossing (Marinho, 2003). Because of the risk of fluoride ingestion, fluoride rinses are not recommended for children under the age of 6 (Twetman, 2004). Fluoride mouthwashes are generally suggested for adolescents and adults who are at an increased risk for caries or have high caries activity.

Mouthrinses are generally composed of water, alcohol, cleansing agents, and flavoring and coloring agents (Marinho, 2003). Cleansings agents include fluoride, astringent salts, antimicrobial agents, and odor neutralizers (Marinho, 2003). Fluoride helps reduce small carious lesions on tooth enamel and acts to make teeth more resistant
to decay. Antimicrobial agents are included in rinses in order to help reduce plaque and gingivitis, as well as controlling bad breath. Astringent salts are incorporated to serve as deodorizers and to reduce bad breath, while odor neutralizers work to inactivate odor causing compounds.

Mouthwashes can be categorized as cosmetic or therapeutic. Cosmetic rinses can temporarily reduce bad breath, but do not actually eliminate the odor causing bacteria (Marinho, 2003). In addition cosmetic mouthwashes do not help reduce plaque, gingivitis, or cavities. On the other hand, therapeutic mouthwashes are able to reduce plaque, gingivitis, cavities and bad breath. Therapeutic rinses specifically contain fluoride which helps prevent or reduce tooth decay. Furthermore, therapeutic mouthwashes act directly on bacteria present in plaque, which does not allow plaque to accumulate and progress to the early stages of gingivitis (Marinho, 2003). Antimicrobial agents found in therapeutic rinses help to eliminate bad breath and inactivate odor causing compounds.

Because tooth decay is the most widespread, chronic childhood disease, school based fluoride mouth rinse (FMR) programs were introduced in the 1970s to reduce the prevalence of caries in children (Divaris, 2012). The school setting was deemed as a favorable environment for a caries prevention program because it could more effectively treat those children who come from a disadvantaged background and experience a higher incidence of dental caries due to lack of access to oral healthcare or financial restraints (Divaris, 2012). Generally the schedule for school based FMR programs is a supervised weekly administration of 10 ml of a mouthwash containing .20% sodium fluoride that
students vigorously rinse for 60 seconds (ASTDD, 2012). For use at home, over the counter fluoride mouthwashes, which contain only .05% sodium fluoride, can be used for daily rinsing (ASTDD, 2012). Stronger fluoride or antimicrobial mouth washes for dental decay or periodontal disease can also be prescribed by a dentist.

According to the American Association of State and Territorial Dental Directors (ASTDD), school based FMR programs costs on average $1.00 per child (ASTDD, 2012). Overall, FMR programs offer various advantages. Weekly fluoride mouth rinsings can be performed at one time in groups, has reliable preventive measures against dental caries, is safe and simple to apply, requires as little time as 5 minutes for an entire classroom, and is cost effective (ASTDD, 2012). Fluoridated rinses can be an effective home oral hygiene system to help prevent or control tooth decay, reduce plaque and tartar formation on teeth, and prevent or reduce gingivitis, but it can be most effective when applied in a community or group of individuals with high caries and low fluoride levels (Divaris, 2012).

**Fluoride Gels/Foams**

Fluoride gels and foams are generally administered by a dentist for patients who are at high risk for dental caries. For individuals at a moderate risk for caries, fluoride gels or foams are recommended every 6 months (Marinho, 2002). High risk individuals can receive gel treatments as often as every 3 months (Marinho, 2002). Some gels and foams can be self-applied at home with the aid of a toothbrush, but the concentration of fluoride in these products is significantly lower.
In a professional setting, a dentist will load the gel or foam into a tray then insert it into the patient’s mouth. Approximately 5 ml of gel is used in a single tray (Marinho, 2002). The patient bites down on the tray for about four minutes. Afterwards, patients are advised not to rinse, eat, or drink for about 30 minutes in order to prolong contact between the fluoride and tooth enamel. A dentist can also make a tray that is custom fitted for a patient’s teeth, and fluoride treatments can be loaded into this tray and be used overnight at home.

Fluoride gels do contain abrasives, such as calcium carbonate, dehydrated silica gels, hydrated aluminum oxides, magnesium carbonate, phosphate salts and silicates, which can be found in toothpaste (Marinho, 2002). The concentration of fluoride in gels is significantly higher than that which is found in toothpaste. Fluoride gels can include sodium fluoride, stannous fluoride and acidulated phosphate fluoride. Typically, gels will consist of 12,300 ppm F (Marinho, 2002). Because this is such a highly concentrated form of fluoride, excessive ingestion of gels can lead to acute toxicity. Nausea, vomiting, headache and abdominal pain are symptoms if overexposure of fluoride occurs (Marinho, 2002). Because of the risk of over ingestion the use of gels in young children is not recommended (Marinho, 2002).

**Systemic Fluoride**

Systemic fluorides are those ingested into the body. These include dietary fluoride supplements and fluoridated water. When compared to topical fluorides, systemic fluorides differ in that during tooth formation, these ingested fluorides are
incorporated into the tooth structure. When fluoride is ingested during the time when teeth are developing, it is deposited throughout the entire tooth surface and can provide longer lasting protection than topical application (ADA, 2005). Because ingested fluoride is present in the saliva, systemic fluoride is also able to offer topical protection. The fluoride is incorporated into the tooth surfaces and dental plaque and promotes remineralization, thus preventing tooth decay.

**Dietary Supplements**

Dietary fluoride supplements, which include tablets, lozenges, and drops, are primarily intended for children who are living in nonfluoridated areas to increase their fluoride exposure, so it is comparable to those children who are living in sufficiently fluoridated areas (ADA, 2005). Fluoride supplements are only available by prescription from a dentist or physician. The supplements are aimed at those children who are at a high risk for tooth decay and work to prevent caries in permanent teeth. It is recommended that fluoride supplements be prescribed (and controlled) in fluoridated communities to avoid overexposure to fluoride ingestion, which can lead to a multitude of health complications.

As seen in Table 3, the correct amount of a fluoride supplement is based on the natural fluoride concentration of the child’s drinking water and the age of the child. In order to achieve the best results, the dietary fluoride supplements should be given daily when the child is 6 months old until he or she is 16 years of age, since this is the age where most of the permanent teeth have completely formed. As indicated in Table 4,
supplemental fluoride is available in lozenges as 1mg fluoride ion, while tablets are offered as 0.25, 0.5, and 1.0 mg fluoride ion. Children over the age of 4 generally are given one lozenge or tablet at night before bed, while children under the age of 4 are prescribed liquid fluoride drops that are administered once daily. Tablets and lozenges are favored because they slowly dissolve in the mouth and can offer an optimal topical effect that aids with tooth enamel remineralization. Additionally, various flavors for both lozenges and tablets are offered, which helps achieve greater acceptability from children.


<table>
<thead>
<tr>
<th>AGE</th>
<th>Fluoride Ion Level In Drinking Water (ppm)*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt;0.3ppm</td>
</tr>
<tr>
<td>Birth-6 months</td>
<td>None</td>
</tr>
<tr>
<td>6 months-3 years</td>
<td>0.25mg/day</td>
</tr>
<tr>
<td>3-6 years</td>
<td>0.50mg/day</td>
</tr>
<tr>
<td>6-16 years</td>
<td>1.0mg/day</td>
</tr>
</tbody>
</table>

(*1.0ppm=1mg/liter of fluoride ion in the drinking water)
Table 4: **Systemic Fluoride Supplements.** Taken from “Current Fluoride Recommendations for the Pediatric Patient” by E. Shick, 2007. Retrieved at http://www.uspharmacist.com/content/d/featured%20articles/c/10229/

<table>
<thead>
<tr>
<th>Product Name</th>
<th>Strength (mg fluoride ion)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Chewable Tablets</strong></td>
<td></td>
</tr>
<tr>
<td>EtheDent</td>
<td>0.25 mg, 0.5 mg, 1 mg</td>
</tr>
<tr>
<td>Luride Lozi-Tabs</td>
<td>0.25 mg, 0.5 mg, 1 mg</td>
</tr>
<tr>
<td>Fluoritab</td>
<td>0.5 mg</td>
</tr>
<tr>
<td>Pharmaflur 1.1</td>
<td>0.5 mg</td>
</tr>
<tr>
<td>Generic sodium fluoride</td>
<td>0.5 mg, 1 mg</td>
</tr>
<tr>
<td>Karidium</td>
<td>1 mg</td>
</tr>
<tr>
<td>Luride-SF Lozi-Tabs</td>
<td>1 mg</td>
</tr>
<tr>
<td>Pharmaflur, Pharmaflur df</td>
<td>1 mg</td>
</tr>
<tr>
<td>Fluoride, Flura*</td>
<td>1 mg</td>
</tr>
<tr>
<td><strong>Drops</strong></td>
<td></td>
</tr>
<tr>
<td>Generic sodium fluoride</td>
<td>0.125 mg/drop, 0.5 mg/mL</td>
</tr>
<tr>
<td>Fluoritab</td>
<td>0.25 mg/drop</td>
</tr>
<tr>
<td>Pediaflor</td>
<td>0.5 mg/mL</td>
</tr>
<tr>
<td>Luride</td>
<td>0.5 mg/mL</td>
</tr>
<tr>
<td><strong>Lozenges</strong></td>
<td></td>
</tr>
<tr>
<td>Fluoride Loz, Flura-Loz</td>
<td>1 mg</td>
</tr>
<tr>
<td><strong>Solutions</strong></td>
<td></td>
</tr>
<tr>
<td>Phos-Flur</td>
<td>0.2 mg/mL</td>
</tr>
</tbody>
</table>

* Regular tablet (nonchewable)
Water Fluoridation

On January 25, 1945, Grand Rapids, Michigan became the first community to fluoridate its public water system to reduce the incidence of dental caries. Since then, public health officials have recommended fluoridation in all communities in order to prevent dental caries prevalence. The Center for Disease Control and Prevention (CDC) has proclaimed community water fluoridation as one of 10 great public health achievements of the 20th century. Today, over 405 million people in approximately 60 countries enjoy the benefits of optimally fluoridated water (Rugg, 2012). As shown in Figure 3, about two-thirds of the US population receives fluoridated water from the public water systems. Nearly 200 million Americans obtain their drinking water from public water systems treated to deliver a concentration of 0.7 – 1.2 parts fluoride to 1 million part water (0.7 – 1.2 ppm), which is the level considered ideal to protect against tooth decay (Rugg, 2012).
Community water fluoridation is the process of adjusting the fluoride content in drinking water to an optimal fluoride level that is recommended by US public health officials (ADA, 2005). The United States Public Health Service (USPHS) determined that the fluoride in water in the range from 0.7 – 1.2 ppm is most effective in reducing dental caries, while minimizing the incidence of dental fluorosis (ADA, 2005). For communities where the level of fluoride is below 0.7 ppm, this would be considered sub-optimally fluoridated water. For a water system to be fluoridated, three components must be added. The first is sodium fluoride, which is a colorless and odorless compound and can be found either in a powder or crystal form. Sodium fluoride is incorporated due to its ability to enhance the strength of teeth through the formation of fluorapatite, which is a component of tooth enamel (Newbrun, 1989). The second component is sodium
fluorosilicate, which is a white odorless and tasteless powder. The final component is fluorosilicic acid, which is a white liquid. All three additives are vital in water fluoridation and together have the protective effect of preventing tooth decay and cavities.

Studies conducted for the past 60 years have consistently shown that community water fluoridation has been a safe and effective method in reducing tooth decay in children, adolescents, and adults (Jones, 2005). Inadequate exposure to fluoride can place children or adults at a higher risk for developing caries. Water fluoridation is able to provide both a systemic and topical effect. The frequent exposure to fluoridated water promotes the remineralization of enamel, which can arrest early dental decay and reverse caries formation. Fluoride that is absorbed in the gut can become incorporated into the tooth surface, thus strengthening the enamel and making it more resistant to acid attacks and preventing decay. Water fluoridation has proven to be an extremely efficient, easy, and inexpensive means because individuals need to simply drink treated water and he or she will receive the benefits of fluoride’s cavity protection (Ripa, 1993). Studies have shown that water fluoridation is effective in reducing dental caries by 20 – 40 % (ADA, 2005).

In addition, fluoridated water can help in the prevention of root decay in the elderly. Because people in the United States are living longer and retaining their natural teeth, older adults are experiencing gum recession. The adults, who have gum recession, are at a greater risk for root decay because the root surface is exposed and susceptible to cariogenic bacteria (Rugg, 2012). According to Table 5, the prevalence of root caries
increases with age: 9.4% among persons aged 20--39 years, 17.8% among those aged 40--59 years, and 31.6% among those aged ≥60 years.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Decayed or Restored</th>
<th>Decayed</th>
<th>Restored</th>
<th>Difference between surveys(^{§})</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>%(^{\dagger}) SE(^{\S})</td>
<td>% SE</td>
<td>% SE</td>
<td>Decayed or Restored</td>
</tr>
<tr>
<td>Age group (yrs)</td>
<td></td>
<td></td>
<td></td>
<td>Decayed or Restored</td>
</tr>
<tr>
<td>20–39</td>
<td>12.11  0.86</td>
<td>9.87  0.66</td>
<td>2.83  0.52</td>
<td>20.20  1.08</td>
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<tr>
<td>40–59</td>
<td>23.31  1.45</td>
<td>13.46  0.96</td>
<td>12.75  1.39</td>
<td>17.79  1.39</td>
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<tr>
<td>≥80</td>
<td>43.17  2.62</td>
<td>20.01  1.02</td>
<td>29.69  3.27</td>
<td>31.62  1.98</td>
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<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
<td>Decayed or Restored</td>
</tr>
<tr>
<td>Male</td>
<td>25.51  1.28</td>
<td>16.38  0.78</td>
<td>12.46  1.25</td>
<td>15.28  1.07</td>
</tr>
<tr>
<td>Female</td>
<td>21.23  1.45</td>
<td>10.90  0.54</td>
<td>12.63  1.46</td>
<td>25.06  1.87</td>
</tr>
<tr>
<td>Race/Ethnicity**</td>
<td></td>
<td></td>
<td></td>
<td>Decayed or Restored</td>
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<tr>
<td>White, non-Hispanic</td>
<td>22.68  1.34</td>
<td>11.67  0.59</td>
<td>14.21  1.46</td>
<td>16.16  1.09</td>
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<tr>
<td>Black, non-Hispanic</td>
<td>27.11  1.67</td>
<td>24.24  1.49</td>
<td>4.11  0.66</td>
<td>25.06  1.87</td>
</tr>
<tr>
<td>Mexican-American</td>
<td>25.46  1.56</td>
<td>21.28  1.10</td>
<td>6.07  1.16</td>
<td>19.95  1.39</td>
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<tr>
<td>Poverty status(^{††})</td>
<td></td>
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<td></td>
<td>Decayed or Restored</td>
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<tr>
<td>&lt;100% FPL</td>
<td>31.09  2.19</td>
<td>26.54  1.91</td>
<td>6.59  1.25</td>
<td>23.50  1.71</td>
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<tr>
<td>100%–199% FPL</td>
<td>30.21  1.70</td>
<td>22.89  1.20</td>
<td>11.50  1.94</td>
<td>23.50  1.71</td>
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<tr>
<td>≥200% FPL</td>
<td>19.93  1.28</td>
<td>8.95  0.64</td>
<td>13.31  1.24</td>
<td>14.54  0.84</td>
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<tr>
<td>Education</td>
<td></td>
<td></td>
<td></td>
<td>Decayed or Restored</td>
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<tr>
<td>&lt;High school</td>
<td>30.46  1.58</td>
<td>24.04  1.17</td>
<td>6.96  1.17</td>
<td>26.17  1.83</td>
</tr>
<tr>
<td>High school</td>
<td>25.63  1.82</td>
<td>15.05  0.92</td>
<td>14.61  1.95</td>
<td>21.19  1.32</td>
</tr>
<tr>
<td>&gt;High school</td>
<td>18.40  1.32</td>
<td>7.29  0.48</td>
<td>12.90  1.42</td>
<td>13.35  0.93</td>
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<tr>
<td>Smoking history</td>
<td></td>
<td></td>
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<td>Decayed or Restored</td>
</tr>
<tr>
<td>Current smoker</td>
<td>32.18  1.66</td>
<td>21.33  1.16</td>
<td>14.33  1.71</td>
<td>32.42  2.34</td>
</tr>
<tr>
<td>Former smoker</td>
<td>21.56  1.37</td>
<td>10.71  0.63</td>
<td>13.49  1.34</td>
<td>15.09  1.09</td>
</tr>
<tr>
<td>Never smoked</td>
<td>18.50  1.29</td>
<td>9.93  0.77</td>
<td>10.26  1.29</td>
<td>13.85  0.76</td>
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<tr>
<td>Total</td>
<td>23.31  1.23</td>
<td>13.50  0.54</td>
<td>12.60  1.29</td>
<td>17.55  0.93</td>
</tr>
</tbody>
</table>
Besides gum recession, older adults also experience decreased salivary flow, or xerostomia. A low flow of saliva can increase their likelihood of developing dental caries (Rugg, 2012). Saliva contains calcium, phosphates, and fluorides, which all facilitate the removal of debris from teeth and help in the early repair of dental decay (Newbrun, 1989).

In a study by Blayney, children in the city of Evanston, who had experienced 14 years of water fluoridation, had 57% less decayed, missing, or filled teeth in comparison to a control group of children in Oak Park, Illinois, which was fluoride deficient (Blayney, 1967). In another study, an epidemiological survey of schoolchildren was completed in 1987 in the United States and was compared to a similar survey in 1980. The survey in 1987 showed that 50% of children aged 5 to 17 years of age were decay free in their permanent dentition, as opposed to only 37% in 1980 (Brunelle, 1990). This decrease in dental caries was attributed to water fluoridation. The data also revealed that the decay rate was 25% lower in children who were living in fluoridated communities (Brunelle, 1990). Finally, in a British study using data from dental surveys collected from 1991-1994, water fluoridation was shown to produce a 44% reduction in dental decay in 5 year old children (Jones, 1997). The study also was able to highlight how children from a lower socioeconomic status (SES) benefited more from water fluoridation and were able to achieve a 54% reduction in dental decay (Jones, 1997). It demonstrated how children with the greatest dental needs would benefit the most from water fluoridation.

Furthermore, water fluoridation has been shown to be highly effective in reducing
the incidence of baby bottle decay. Baby bottle decay, also referred to as early childhood caries, is a dental disease that is characterized by severe decay in the teeth of infants and toddlers (Armfield, 2010). Water fluoridation is particularly effective in preventing baby bottle decay in children from a lower SES because it the only preventive measure that does not require a visit to a dental professional (Armfield, 2010). With a plethora of scientific literature documenting the effectiveness of water fluoridation, respected and credible professional organizations, such as the ADA, CDC and USPHS, leading scientists and healthcare professionals, and governments around the world have all supported community water fluoridation as a means of preventing dental decay and maintaining good oral health.

Community water fluoridation’s cost effectiveness is one of the biggest reasons why it is so strongly supported. The average cost of a community to fluoridate its water is estimated to be approximately $.62 a year per person in large communities and $3.90 a year per person in small communities (ADA, 2005). As a result, water fluoridation saves a tremendous amount of money and an individual can have a lifetime of fluoridated water for less than the cost of one dental filling (ADA, 2005). In a published study conducted by the CDC, an economic analysis found that the annual per person cost savings in fluoridated communities ranged from $16 in small communities of less than 5,000 people to $19 in large communities consisting of greater than 20,000 people (Griffin, 2001). Through fluoridation, communities can save on the treatment costs while also improving the oral health of all residents. Besides cost effectiveness, community water fluoridation distinguishes itself from other forms of fluoride therapy because it is not dictated by age,
income, education or race (Ripa, 1993). Simply by drinking fluoridated water, people in a community receive benefits, especially those individuals who do not have access to regular dental care. Unfortunately, not everyone lives in a community with a centralized, public or private source that can be fluoridated.

Nonetheless, fluoridation of community water systems has drawn criticism from individuals and groups that consider fluoride detrimental to systemic health. Opponents of water fluoridation regard fluoride as a carcinogen and associate it with cancer (Newbrun, 1989). Others have suggested that a higher incidence of bone fractures may be greater in communities that have a fluoridated water source (Newbrun, 1989). It has been shown that large doses of fluoride can be harmful, especially to the bones and teeth. Bone damage may occur in people whose drinking water contains fluoride levels from 2 to 3 ppm or more (Ripa, 1993). Ingesting higher amounts than the recommended fluoridated levels of 1 ppm can lead to fluorosis and potentially fluoride poisoning (Ripa, 1993). Fluorosis is a nonfatal condition that is characterized by mottling, or discoloration, of the teeth. Fluoride poisoning is a potentially lethal event that can occur following the consumption of excessive amounts of fluoride either from supplements, fluoridated dentifrices, rinses, or water sources. For young children, a dose of 400 mg at one time can be lethal (Dhar, 2009). For adults, a single lethal dose is 5 grams, or 5,000 mg of fluoride (Dhar, 2009).

Besides public water systems, bottled water can also be a source of systemic fluoride. Because the fluoride content of bottled water can vary greatly, less than optimal levels of fluoride may be found in bottled water (ADA, 2005). In the same regards, home
water treatment systems, such as faucet water filters and under the sink filters, can reduce the fluoride levels in water. Depending on the type, quality, condition, and age of the water filter, either a significant amount of fluoride can be removed from the water supply or relatively little (ADA, 2005). Those people who are drinking water with home filters as their primary source can potentially lose the decay preventive effects of optimally fluoridated water that is available through the community water supply.

FLUOROSIS

Dental fluorosis is hypomineralization of tooth enamel. It only occurs in children aged 8 years and younger since this is the age when permanent teeth are developing under the gums (Fomon, 2000). Enamel formation of permanent teeth occurs from birth until five years of age. Once tooth enamel has completely formed, dental fluorosis cannot develop even if a large amount of fluoride is consumed (Fomon, 2000). Because of this, adults and adolescents are not susceptible to dental fluorosis. Since dental fluorosis occurs under the gums when teeth are still forming, teeth that have already erupted are not at a risk for developing this disease (Fomon, 2000).

Fluorosis is caused by ingesting too much fluoride over a long period of time when teeth are still developing under the gums. The severity of the fluorosis depends on the dose, duration, and timing of the fluoride intake (Whelton, 2004). Increases in the occurrence of dental fluorosis have been a result of more sources of fluoride being introduced in order to protect against dental decay. These sources of fluoride can range from fluoridated water, food, beverages, fluoridated dentifrices, and dietary supplements.
As a result, dental fluorosis can occur in all communities, even in those that have low fluoride levels in drinking water (Whelton, 2004).

Public health officials consider a concentration of 0.7 – 1.2 parts fluoride ions to 1 million parts water (0.7 – 1.2ppm) to be the upper acceptable limit (Levy, 2003). If a higher amount of fluoride is ingested, either at one time or over a period of time, dental fluorosis can develop. According to H.T. Dean from the USPHS, fluorosis can be classified according to the following categories: questionable, very mild, mild, moderate, moderate to severe, and severe (Whelton, 2004).

- Very mild dental fluorosis involves opaque white patches or streaks ranging from small areas on the cusps of the teeth up to 25 percent of the tooth surface.
- Mild dental fluorosis involves an impaction of up to 50 percent of the tooth surface.
- Moderate dental fluorosis involves 100 percent of the tooth surface being affected with some pitting.
- Severe dental fluorosis affects 100 percent of the tooth surface with more pitting and brittleness.

Over time, particularly with moderate and severe cases, the white patches become progressively discolored, going from yellow to orange to brown, making the condition visually unappealing. In addition, pits on the enamel surface of the teeth develop and abnormal hardening of the bones occurs. In its very mild and mild forms, fluorosis is generally not noticeable to the affected individual and requires the expertise of a dental
health professional in order to detect (Whelton, 2004). In its modest and severe forms, dental fluorosis is characterized by esthetic changes in tooth color and surface irregularities, which are both easy to detect.

Proponents of fluoride therapy argue that dental fluorosis is merely a cosmetic problem, not a health problem. Until the fluorosis becomes severe, the argument is that it does not interfere with the functioning of the tooth or increase susceptibility to dental decay (Levy, 2003). The risk of developing of dental fluorosis can be weighed against the benefits of fluoride and the lower level of decay that can save on dental treatments, patient discomfort, and tooth loss.

Fluorosis can be prevented by closely monitoring the use of fluoridated products in young children. For one, parents and caretakers of young children can help by putting only a pea-sized amount of fluoride toothpaste on the child’s toothbrush before each brushing (Fomon, 2000). This can help minimize the amount of fluoride ingested if the child inadvertently swallows the toothpaste. Secondly, dietary supplements are a beneficial means of obtaining fluoride in communities where the water is not fluoridated, but as shown in Table 4, these supplements must be prescribed judiciously according to the recommended dosage released by the ADA. Taking fluoride supplements inappropriately is one of the most common causes of dental fluorosis. Another means of prevention would be to know the fluoride concentration in the drinking water being given to young children. If the drinking water is fluoridated at the recommended levels of 0.7 – 1.2 ppm F, then fluoride supplements, such as drop and tablets, should not be used (Levy, 2003). Finally, children younger than 6 years of age should not be given fluoride mouth
rinses because there is a risk of developing dental fluorosis if these mouthwashes are repeatedly swallowed (Fomon, 2000).

Dental fluorosis can be treated cosmetically by a dentist. Generally tooth bleaching and composite restorations are commonly used treatments. Bleaching is usually used for superficial stains associated with moderate forms of fluorosis, while composite restorations are used to treat more unaesthetic situations, primarily seen in severe fluorosis cases (Levy, 2003).
DISCUSSION

Among the topical applications of fluoride, fluoride toothpaste is the most beneficial because it combines the use of fluoride as well as the mechanical removal of debris on teeth. When fluoride toothpaste is used, a high concentration of fluoride is maintained in the oral cavity during brushing. When brushing with fluoride toothpaste is performed regularly, fluoride concentration in the oral cavity’s biofilm can last up to 10 hours. Brushing with fluoride toothpaste protects not only the cleaned surfaces on teeth, but also provides fluoride to unremoved debris of biofilm which can help in controlling caries development. Toothpaste containing 1,000-1,500 ppm fluoride has been proven to be effective in controlling caries formation. For patients who are caries active or at a high risk for dental caries, low level fluoride toothpaste (500 ppm F) is not sufficient in preventing or reducing dental caries.

Fluoride mouthrinses are primarily indicated for those individuals living in areas with irregular fluoride exposure and are at an increased caries risk or are currently dealing with high caries activity. Fluoride mouthrinses have the advantage of being available for daily home use or can be used in organized school based programs. Fluoride mouthrinses are most effective when used in supervised, school based programs that target high caries groups of children in non-fluoridated communities. Because fluoride mouthrinses are not recommended for children under the age of 6, this can limit the population that can be treated. Due to the increased exposure to fluoride from other sources, the effectiveness of school based fluoride mouthrinses may be in decline.
Fluoride mouthrinses are cost effective in a school setting for children at high risk for caries, but its cost effectiveness as a universal population wide strategy for fluoride exposure is unreasonable.

The effectiveness, ease of application, and relative safety of fluoride varnish establishes it as the preferred choice over other professionally applied topical fluoride treatments, such as gels and foams. Fluoride varnish applications is an attractive option because it only requires about 5 minutes and does not need special preparation of the teeth or any expensive equipment. In addition, varnishes contain a negligible amount of fluoride that even if ingested, will not be toxic to overall systemic health. On the other hand, fluoride gels and foams require a larger dosage which can be detrimental if accidentally swallowed by the patient. Moreover, fluoride gels and foams are loaded into mouth trays, which can cause patients, who suffer with gag reflexes, unpleasant discomfort. While it is more cost effective than fluoride gels and foams, the overall cost of varnish application is higher than other topical therapies. Unless fluoride varnishes are applied in school based programs, similar to fluoride mouthrinses, populations that include low income individuals or new immigrants and refugees may not have access to this preventive treatment due to financial constraints or lack of access.

Fluoride supplements have contributed significantly to preventing caries formation; however, due to fluoride’s availability in a wide variety of applications, supplements are no longer preferred. Compliance with fluoride supplements’ recommended dosages over a long period of time is the key factor in this fluoride therapy falling out of favor. Simply, few people are willing to use supplements with sufficient
regularity to achieve a positive effect. Furthermore, fluoride supplements also require a prescription from either a dentist or physician, which can be an obstacle to those individuals who have limited access to dental or medical services. There has also been evidence that supplements can cause dental fluorosis when not administered by following the recommended dosage. Because dental fluorosis causes staining of the teeth, the public may associate fluoride with negative cosmetic effects. This could result in opposition to overall fluoride use, which could jeopardize the other forms of fluoride therapy that have proven to be successful in preventing tooth decay and caries formation. In addition, dietary fluoride supplements are only intended for use among high caries risk children between the ages of 6 months to 16 years that are living in non-fluoridated areas. This limits the range of distribution for supplements as opposed to other forms of fluoride treatment. Finally, other fluoride therapies are simply more cost effective and efficient in preventing caries formation. Due to these factors, fluoride supplements may be best suited for administration to high caries risk populations and not be defined by age groups or areas of residence.

Of all the methods of fluoride therapy, fluoridated water should be considered the most effective and safe means of delivering fluoride to a population. The mechanism by which fluoridated water reduces dental caries is that fluoride is ingested and is returned to the oral cavity as fluoride enriched saliva. In order for fluoridated water to be efficacious, it needs to be consumed continuously to bathe teeth with the fluoride enriched saliva. Because the concentration of fluoride needed to reduce dental caries is a fairly small amount (0.7-1.2), the difference in living in fluoridated area as opposed to
one that is not, can have a remarkable effect on a person’s oral health. In addition, fluoridated water does not only have to be drunk, but can also be used in cooking. Fluoride can still be available through food that is prepared with fluoridated water. Overall, controlled water fluoridation is currently viewed as the most effective and least expensive means of caries prevention.
CONCLUSION

Among the various forms of topical applications of fluoride, fluoride toothpaste is the recommended choice. Because toothpaste can be self-applied by an individual in his/her own home, this is more cost effective in comparison to topical varnishes, gels, or foams that must be administered by a dental health professional. In addition, fluoride toothpaste requires only a short amount of time in order to be applied, whereas other forms of topical treatment requires the expertise of a dental health professional.

As for systemic methods of fluoride delivery, community water fluoridation is most effective. Fluoridation of community water supplies remains the most cost effective, economical, and efficient means of preventing dental caries.

When comparing topical and systemic fluoride treatments, systemic fluoride, particularly water fluoridation, would be more effective in preventing dental caries. Although available in most countries, the regular use of topical fluorides, such as fluoride toothpaste and mouthrinses, varies from country to country and more importantly by socio-economic level. Water fluoridation is able to provide the greatest benefit to those populations that can least afford preventive and restorative dentistry.

A combination of topical and systemic fluorides would be the most effective means of preventing dental caries formation. Both fluoridated water and fluoride toothpaste should be recommended to all individuals. The prevalence of dental caries throughout the world would see a significant decrease if populations had access to fluoridated communal water supplies, as well as topical fluoride agents on regular basis.
Combining topical and systemic methods of fluoridation will yield the best results for caries prevention while also working to maintain the recommended fluoride dosage there by following the guidelines of the ADA.
# LIST OF JOURNAL ABBREVIATIONS

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<th>Abbreviation</th>
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<tr>
<td>Adv Dent Res</td>
<td>Advances in Dental Research</td>
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<tr>
<td>J Am Dent Assoc</td>
<td>Journal of the American Dental Association</td>
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<tr>
<td>J Dent Res</td>
<td>Journal of Dental Research</td>
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<td>MMWR Surveill Summ</td>
<td>Morbidity and Mortality Weekly Report. Surveillance Summaries</td>
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REFERENCES


Walsh T, Worthington HV, Glenny AM, Appelbe P, Marinho VCC, Shi X. (2010) Fluoride toothpastes of different concentrations for preventing dental caries in


VITA

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EDUCATION

UNIVERSITY OF CALIFORNIA SAN DIEGO
B.S. General Biology 2007  La Jolla, California

BOSTON UNIVERSITY SCHOOL OF MEDICINE
M.A. Medical Science - Oral Health Science 2013  Boston, MA

EMPLOYMENT

DR GARY HIRSH ORTHONDONTICS, LA JOLLA CA  April 2006-2007
DENTAL ASSISTANT

- Performed starts on patients, which included taking impressions, panoramic and cephalogram x-rays and facial and intra-oral photos
- Poured stone models for case studies
- Sterilized instruments and prepared examination trays
- Placed brackets on study models for indirect bonding (IDB) trays
- Used Vacuform to make IDB trays, bleaching trays, and mouthguards

DR IRVIN SILVERSTEIN, LA MESA CA  December 2007-April 2008
DENTAL ASSISTANT

- Assisted with osseous surgery, dental implants, sinus lifts, and soft tissue grafts
- Performed full mouth x-rays
- Sterilized instruments,
- Maintained a clean work environment and stock inventory
- Prepared surgery cassettes
**Volunteer Experience**

**UCSD Student Run Free Dental Clinic**

**UCSD Downtown Clinic Manager**  
**Spring 2007-2008**

- Overseeing clinic operations such as managing doctors, volunteers, patients, and facility
- Preparation of tray set-ups for periodontics, restorative, oral surgery, orthodontics, endodontics, prosthodontics, hygiene, and cosmetics
- Obtain a working knowledge of equipment such as Digital Kodak X-rays and Practiceworks Software

**Dentist Recruiter/Scheduler (Downtown clinic)**  
**Fall 2007-Spring 2008**

- Accommodating dentists issues and concerns
- Schedule and follow-up dentist in monthly volunteering schedule

**UCSD Pre-Dental Society**  
**Spring 2006- Fall 2008**

**UCSD PDS Volunteer**

- Coordinated palate deliveries at Dr. Silverstein’s office and organized items for delivery to the three clinics
- Coordinated and organized donations at storage unit
- Participated as a DHA ambassador teaching children at Baker elementary on oral healthcare
- Participated in selling dental kits and tabling for the organization along Library Walk
- Solicit donations at California Dental Association (CDA) convention

**USS Pacific Partnership Peleliu Southeast Asia Humanitarian Trip**  
**May 2007**

- Assisted in scaling and root planning, prophy, and extractions, removal of abscess
- Performed bite wing x-rays
**Thousand Smiles**  
**MAY 2007**

- Traveled to Ensenada, Mexico and volunteer every three months to assist with physicians, nurses, speech therapist, and dentist to provide healthcare
- Took facial and intra-oral photos of patients
- Occupied children in the wait room by educating them on proper hygiene
- Assisted with basic day-to-day operations including assisting, setting up trays, sterilization, x-rays
- Observed cleft palate surgery in operating room

**USNS Pacific Partnership Mercy**  
**JULY 2008-SEPT. 2008**
**Southeast Asia Humanitarian Trip**

- Assisted in scaling and root planning, amalgam and composite fillings, root canals, dentures, prophy, and extractions, removal of abscess, irrigating sinus, biopsy of oral lesions, and Cerec crown preps
- Obtained hands on experience and guidance from different Partner Nations (U.S., Japan, India, Australia, Indonesia, and Canada) the Armed Forces, Project Hope, East Meets West, and Operation Smiles
- Worked as a dental technician/assistant in field dentistry, traveling across 6 different countries