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A Theoretical Study on the Effects of Dental Fluoride Usage

Marwa I Khalil [*1], Asma Khalid [1], Dunia Hamid [1], Rafal Deaa Abd Alamer [1], Rokan Salman Dawood [1]

[1] Iraq/ Baghdad / Adhamiyah/ Hibat Katon, street 22, district 308. Postbox: Kaifa : 7266.
[*] https://orcid.org/0000-0001-6948-9260

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* Corresponding Author: Marwa I Khalil
Email address: marwaibrahim2007@outlook.com
https://orcid.org/0000-0001-6948-9260

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Abstract

Dental caries are commonly prevented by applying dental products containing Fluoride, which decreases and promotes enamel demineralization and remineralization, respectively. Therefore, this study focuses on various usage of dental fluorides and their effects. The prevention procedure is always achieved by topical application of fluoride products such as toothpaste, mouth rinse, gel, and varnish, in addition to the systematic application of Fluoride. In some countries, Fluoride is commonly added to water, salt, and milk to prevent teeth caries. Meanwhile, Fluoride is also prescribed as a medical treatment for early dental caries. However, Fluoride is a double-edged sword, and the excessive intake of Fluoride will cause toxic reactions and lead to dental fluorosis, especially during tooth development.

Keywords: Dental, enamel, fluoride, mouth rinses, saliva, Toothpaste.

Introduction

Fluorides are regarded as effective materials in controlling dental caries, which can benefit the prevention and treatment (Figure 1). Fluoride is extensively spread in nature and is available in different percentages in soils, water, and animals (1). However, water-soluble Fluoride is the most essential form for organisms. Because Fluoride is not evenly distributed in soil, fluoride concentration in water differs in various areas. The Plants naturally contain a particular amount of Fluoride absorbed from the soil and water. Besides, plants can increase fluoride content by absorbing deposited Fluoride on the leaves or directly absorbing the Fluoride in the heaven (1, 2). According to the World Health Assembly in 2007, the resolution was given that universal access to Fluoride for caries prevention was to be part of the basic right to Human Health. There are three basic fluoride delivery methods for caries prevention:

community-based (fluoridated water, salt, and milk), professionally administered (fluoride gels, varnishes), and self-administered (toothpaste and mouth-rinses). However, the combination of different methods is used globally in many communities. According to previous publications, the maintenance of low levels of oral cavity fluoride effectively prevents caries. Plaque, saliva, oral soft tissue surfaces, and loosely bound enamel surfaces are important fluoride reservoirs. Strategies that provide regular, low-level exposure to Fluoride in the community, such as fluoridated water, salt and milk, and fluoride toothpaste, are superior in making a cheap fluoride cost compared with professional application of gel and varnish. This method secures a continuous low level of Fluoride at the enamel surface through the slow release of Fluoride from the depositions of calcium fluoride accumulated on the teeth surface at the time of application. Consequently, this is considered an important method in caries-susceptible populations.

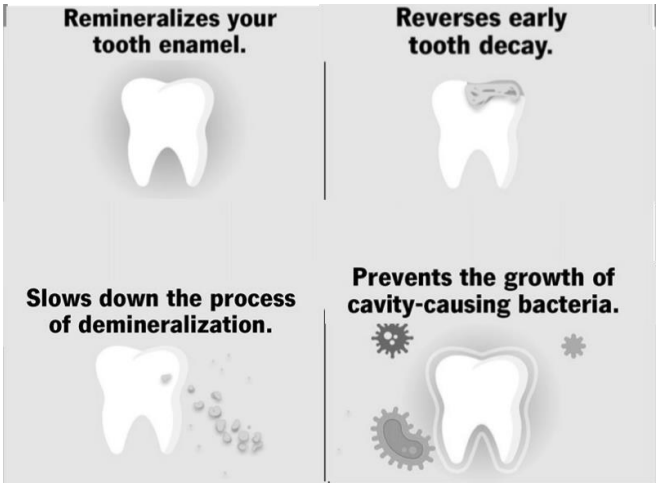

Figure. 1: benefits of fluoride

Fluoride: Intake and Mechanism

The primary source of human Fluoride comes from water and food. Water Fluoride is easily absorbed by the human body. However, the amount of Fluoride absorbed by the body from drinking water depends on its concentration and the amount of drinking water. It also depends on other factors such as the age, living habits, local temperature, and other factors. Adults drink about 2500–3000 ml of water per day. All foods, including plant or animal food, contain a certain amount of fluoride, but the content of fluoride among them is widely different. Plant food, such as grains, vegetables, fruits, and so on, often has significant differences in fluoride content due to different regions. The fluoride in the air is not the primary source of human fluoride. Unfortunately, under some special environ- mental conditions, air can be pollute by fluoride. In this way, the fluoride in the air can enter into the human body through the respiratory tract, causing fluorosis. In addition, there are other possible sources of fluoride. For example, some oral topical fluoride products have very high fluoride concentration. If they are use unproperly without the guidance of doctors, it may lead to an increase in fluoride intake. The total intake of fluoride is the sum of the intake of fluoride from the air, water, diet, and so on. It contains two meanings: one is the total adaptive intake, which refers to the

physiological demand for preventing and maintaining normal biological functions of the body; the other is the total safe intake, which refers to the maximum amount that the body needs. When the body takes more chemicals than the safe intake for a long time, it will lead to chronic poisoning. Most researchers recommended a proper daily fluorine intake of 0.05-0.07 mg to avoid toxicity (5). It is believed that the primary Mechanism of fluoride to prevent caries is by reducing demineralization and promoting enamel remineralization. Besides, fluoride has effects on the microorganism (Figure.2).

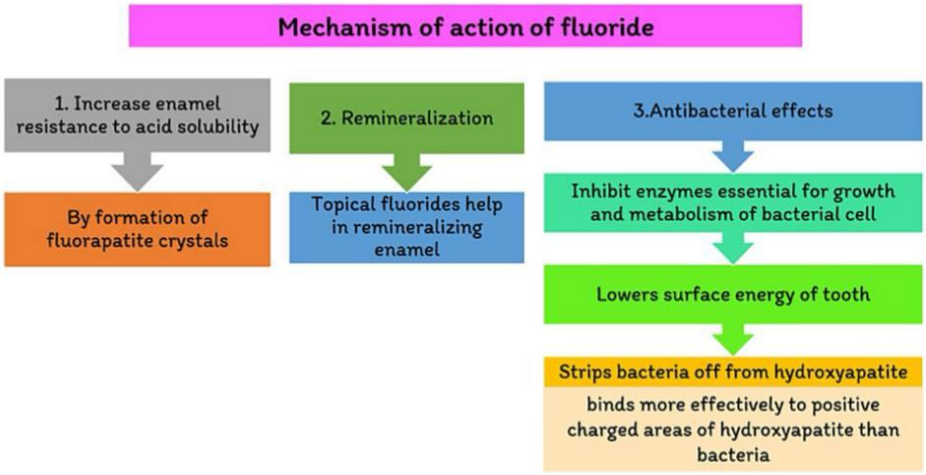

Figure. 2: Flowchart showing the mechanism of action of fluoride

Under normal conditions, the solubility of enamel in acid buffer varies according to the fluoride concentration. When the fluoride concentration reaches 0.05 mg/l, the enamel's solubility will be reduced. Fluorine can be combined with free hydroxyapatite (HA) to form fluoro hydroxyapatite (FHA) in the saturated solution of hydroxyapatite, which can be redeposited in enamel; this process is called remineralization. Conversely, the unsaturated hydroxyapatite solution enables the fluorine to enter directly into the crystal and form FHA or replace it with the hydroxyl ion in enamel to form fluorapatite (FA). The decreasing oral pH value leads to tooth demineralization and eroded teeth. Subsequently, calcium fluoride dissolves and releases fluoride and calcium ions into saliva. When the calcium and phosphorus ions in saliva are saturated, they will make the minerals return to the teeth. If this process happens on the surface of the demineralized crystal, a new crystal surface will be formed. Dental professionals also use fluoride products to manage tooth caries (6). Surface fluoride deposition on the demineralized enamel enhances remineralization and consequently treats tooth caries. Many fluoride products, such as sodium fluoride (NaF) and silver diamine fluoride (SDF), are commonly used to treat dental caries, mainly earlies tooth decay (7). Other publications mentioned that the annual usage of 38% of SDF for older adults disclosed to root surfaces lowered the prevalence of new root carious lesions by at least 50% (8).

Toxic and Fluorosis

Increased fluoride consumption rises the risk of systematic diseases, toxicity, and fluorosis. Published studies revealed the relationship between fluoride toxicity and molecular

mechanisms (1, 2). They found that Fluoride produces oxidative stress, regulates Fluoride redox homeostasis, leads to mitochondrial damage and endoplasmic reticulum stress, and alters gene expression (1, 2).

Acute toxicity

It occurs if a hefty dose of fluoride products is taken by mistake at once. The most common clinical signs of acute fluoride toxicity include nausea, vomiting, diarrhea, and intestinal bleeding in severe circumstances. Organs damage such as heart, liver, kidney, and some advanced cases coma and die of patient or recovery within 4 hrs. The principles of emergency treatment include emetic, gastric lavage, oral administration of calcium or intravenously injection of sugar, and liquid supplement accompanied by symptomatic treatment.

Chronic toxicity

Chronic fluoride toxicity can be caused by long-term excessive intake of Fluoride. According to the different sources of Fluoride, chronic fluoride toxicity can be divided into Fluoride endemic and industrial fluorosis. Endemic fluorosis is a disease that occurs in a specific geographical environment. It is a chronic systemic accumulation of fluorosis caused by excessive intake of Fluoride through water, air, or food. Drinking water with high fluoride concentrations and living with domestic coal pollution may cause endemic fluorosis. The degree of damage to the body mainly depends on the dose of Fluoride. There is no significant difference in the effect of fluoride from different sources on the body. Industrial fluorosis usually occurs in workers who work with cryolite and bauxite for a long time. The Fluoride clinical manifestations in chronic toxicity are dental and skeletal fluorosis. Because dental fluorosis is manifested early in cases of fluoride toxicity, dental fluorosis can be used as a biomarker of fluoride toxicity. Chronic exposure to excessive Fluoride is associated with children's dental Fluoride intelligence scores. A study found that dental fluorosis is positively related to the loss of high intelligence (9). There are three methods to prevent chronic fluorosis.

1. The concentration of Fluoride in water must be controlled. Water fluoridation is an effective way to prevent caries. However, the fluoride concentration should be monitored in case of dental fluorosis. In areas with a high content, methods must be used to remove Fluoride from the water.
2. Domestic coal pollution should be removed as much as possible.
3. Industrial fluoride pollution prevention.

Dental fluorosis

Dental fluorosis is defined as excessive fluoride intake during the mineralization period of tooth development. It can be discovered early and quickly. The clinical manifestations including (Figure.3) :

- The white strips on the surface of enamel, and the strips can fuse to form patches, even spreading to the whole surface.
- Some of the strips or plaques are yellowish or brown.
- Dental fluorosis in severe cases, accompanied by enamel defect or tooth defect.

Dental fluorosis mainly occurs in permanent teeth, while less in primary teeth because it is difficult for the Fluoride to pass through the fetal blood barrier. The number of teeth involved in dental fluorosis is related to the length of time living in the high-fluoride area during tooth mineralization. If a child moves into the high-fluoride zone after the age of 6–7, dental fluorosis almost does not appear. The severity of dental fluorosis depends on the degree of excessive fluoride intake. If Fluoride is severely excessive, the enamel's Fluoride is discolored, and the tooth tends to stain or collapse. The principal reason for abnormal mineralization in dental fluorosis may be the high concentration of Fluoride, which can inhibit the activity of alkaline phosphatase, which is essential to bone and tooth formation.

Figure. 3: Shows dental fluorosis. A. the Mild with slight accentuation of the perikymata. b. the Moderate, showing a white opaque appearance. c. the Moderate, white opaque enamel with some discoloration and pitting. d. the severe. Pamela DenBesten and Wu Li. Chronic Fluoride Toxicity: Dental Fluorosis. Monogr Oral Sci. 2011 ; 22: 81–96. doi:10.1159/000327028 (10)

The primary source of excessive fluoride intake is water (11). Therefore, the principle of preventing dental fluorosis is avoiding absorbing excessive Fluoride from water during the tooth mineralization. The non-fluoride factors may also contribute to dental fluorosis. Previously published research (12) discussed the effect of components contents on the risk of dental fluorosis, and it reported that high levels of F, A5l, As, Pb, and Cr and low levels of Se, Zn, Cu, B, Ca, and P increase the risk of dental fluorosis. It suggested that taking measures to decrease the contents of F, Al, As, Pb, and Cr in the environment and increase the contents of Se, Zn, Cu, B, Ca, and P simultaneously help control fluorosis. In addition, the gene is regarded as a relevant risk factor for dental fluorosis (13). Increasing evidence shows that an individual's genetic background could increase the risk of fluorosis when other factors, like fluoride exposure, remain the same(14,15). MMP20 was supposed to be related to the various phenotypes of dental fluorosis and may serve as a protective marker (16). These would provide some evidence for identifying people at risk of developing dental fluorosis in their later lives. At the same time, we should distinguish dental fluorosis from enamel hypoplasia. Enamel hypoplasia usually has clear boundary strips in one or more teeth. On the contrary, the strips of dental fluorosis have no definite boundary. The symptom regularly appears in several teeth, and patients often have a history of living in the high-fluoride area. Concerning how to treat dental fluorosis, bleaching, and resin infiltration treatment both work for mild dental fluorosis(16).Nevertheless, a complete crown prosthesis is better for severe dental fluorosis. A porcelain veneer is also used in severe cases (17). Recently, some clinical studies have discussed the effect of at-home bleaching and consider it effective and efficient (18). When removing the abnormal enamel affected by Fluoride, it is necessary to protect the health Fluoride tissue as much as possible. Micro abrasion can protect healthy tooth tissue and treat dental fluorosis(19).

Skeletal fluorosis

Skeletal fluorosis (Figure.4) may impair muscle movement, ligament calcification, increased osteosclerosis, and cancellous bone formation in the advanced stage. It may also limit joint movement, cause muscle atrophy, and deform bone, spine, and significant joints (2,20,21).

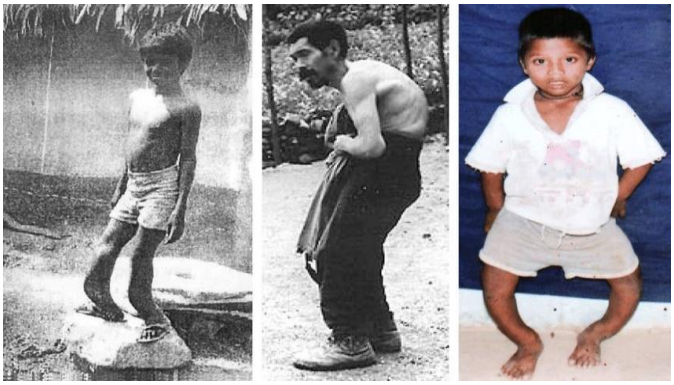

Figure. 4: Shows the maximum ill effects of fluoride intake are detected in the neck, spine, knee, pelvic and shoulder joints, which is referred to as skeletal fluorosis) (Skeletal fluorosis (fluoride and fluorosis and nalgonda: http://www.fluorideandfluorosis.com, http://www.nalgonda.org) (22).

Fluoride Systemic Use

Oral administration of fluoride is the correct way for systematic use. The fluoride is absorbed via the digestive system into blood vessels and transported to teeth and saliva to avoid caries. Fluoride can be used in various forms, including fluoridated water, salt, milk, and tablets.

Fluoridated water

Adjusting the concentration of fluoride in water is important to prevent caries but without reaching dental fluorosis. The acceptance of fluoride water is endorsed by more than 150 science and health organizations like WHO and the International Association of Dental Research (IADR) (4, 10, 21). The first country in South Asia that used fluoridated water was Singapoura in 1958, which covers 100% of the population and squares with a reduction of dental caries and improved oral health status (22). Some researchers assessed disability-adjusted life years (DALYs) and DALY rate due to dental caries preventable through water fluoridation in Iran, and they found that in 2016, DALYs were 14,971 (95% uncertainty interval 7348–24,725) and DALY rate was 18.73 (9.19–30.93) (23). The results indicated that water fluoridation acted as a vital role in dental public health at the national level. According to the WHO's recommendation, the allowed fluoride level in water is 1.5 mg/L.

Salt fluoridation

Unlike water fluoridation, Fluoride is added to salt and is absorbed into the body by eating this salt. The salt fluoridation used in a dental research project in Colombia (24) is now extended into more than 20 countries (4). Although salt fluoridation is not as widespread as water fluoridation, it is still a supplement to water fluoridation, especially in the low-fluoride areas and no tap water areas. The dietary habits are different in different countries; therefore, the amount of salt intake in different countries is different. Thus, the content of added fluoride

must depend on specific conditions. Although salt fluoridation is not restricted by water service, the most disadvantaged point of this method is that the fluoride content is precisely hard to control. If someone prefers to eat salty, it is more likely for him/her to get dental fluorosis. Moreover, considering that few citizens know how much fluoride is added to salt, the government participating in water fluoride is a better choice.

Milk fluoridation

Milk fluoridation is another way to use fluoride, which means the fluoride is added to milk or milk powder. However, it has the same shortcomings as salt fluoridation- difficult to control. Milk contains nutrients that help to buffer acid and may reduce the risk of dental caries after exposure to a sugar beverage. Previous research studied the effect of rinsing with water, non-fluoridated milk, and fluoridated milk on acidic dental plaque; the results showed that rinsing with fluoridated milk increased the pH value of acidic plaque to the resting level faster(25). Considering the safety of using fluoride, fluoride intake is controlled strictly. Therefore, propaganda and education about milk fluoridation are essential.

Fluoride tablet

Fluoride tablets are a supplementary method of systemic application of fluoride for children, especially for children who live in areas with low fluoride content and when the government does not carry out a water fluoridation policy. Fluoride tablets must be used under dentists recommendations and parents supervision. A study assessed adherence to oral fluoride and barriers to adherence in the community without water fluoridation, and more than half of parents found that they either had not or did not know whether their children had received fluoride the day before, however, the adherence to fluoride tablets in the primary care setting is low (26). Choosing water fluoridation as a systemic fluoride application method is better.

Topical Application of Fluoride

The topical way to use fluoride is to apply fluoride directly to the tooth's surface. It is a double-edged sword. This method can increase the topical concentration of fluoride quickly and make fluoride play a better role in prevention and treatment. The combination of these two methods will enhance the effect of fluoride. On the other hand, higher topical fluoride concentration may cause toxic effects, such as dental fluorosis. In addition, fluoride can enter the digestive tract through the oral cavity, which will then be absorbed into the blood, resulting in toxic effects. However, if we use fluoride correctly, we can almost completely avoid its toxic effects. Therefore, it is important to know how to use fluoride correctly. The common ways to use fluoride topically are through fluoride toothpaste, mouth rinse, varnish, gel, and foam.

Fluoride toothpaste

Many different types of toothpaste are applied to prevent caries and improve oral health. Around 90% of these contain fluoride, a mineral found in relatively low concentrations in fresh and seawater. Fluoride toothpaste provides a higher mineral level than any other source. It is a cheap and convenient way to promote dental health, recognized by the Centers for Disease Control and Prevention as "one of 10 great public health achievements of the 20th

century." Different kinds of fluoride toothpaste exist, such as sodium fluoride and stannous toothpaste. Fluoride toothpaste is generally believed to have a noticeable effect on caries prevention (27,28).

Sodium fluoride toothpaste

It is crucial to keep the activity of fluoride ions in sodium fluoride toothpaste. In the earlier year, the fluoride ion lost its activity due to the incompatibility of sodium fluoride with calcium carbonate, calcium phosphate, and other friction agents in toothpaste, and the prevention effect was not evident(29). However, after the reasonable selection of friction agents, such as acrylic plastic, calcium pyrophosphate, or silica, it is proven that the control effect is positive. Nowadays, sodium fluoride toothpaste is widespread, and it does not have the defect of staining teeth.

Stannous Fluoride

Stannous fluoride toothpaste can prevent caries, provide antibacterial function, and relieve dentin hypersensitivity (30). The researchers studied the action mode of stannous and sodium fluoride toothpaste on anti-biofilm properties. The results revealed that stannous fluoride toothpaste had a better antibacterial effect on microbial biofilm. Moreover, stannous fluoride toothpaste could regulate microbial composition within a multi-species biofilm. However, long-term use of stannous fluoride toothpaste could lead to tooth staining. The tooth discoloration caused by stannous fluoride is due to the reaction of the tooth with the tin ion present in the formulation. In addition, stannous ions may cause the toothpaste to taste bad. At the same time, the stannous ion quickly loses its activity in toothpaste. Recently, researchers have tried to find a new formula. First, the composite chelating technology can effectively stabilize the stannous ion in the toothpaste during storage and transportation. Moreover, the stannous ion can still be released rapidly during brushing. Meanwhile, the stannous ion is stabilized by the composite chelating technology to resist the staining problem of stannous fluoride. It reported that adding zinc phosphate could significantly improve the stability of stannous ions more effectively than other stabilization methods. Besides, researchers are looking for more effective fluoride toothpaste to prevent caries. A study showed that incorporating 2% arginine in sodium fluoride toothpaste significantly increased the remineralization of enamel caries-like lesions compared to sodium fluoride toothpaste (31).

Fluoride mouth rinse

When fluoride is added to mouth rinse, it is called fluoride mouth rinse. Although mouth rinse only stays in the oral cavity for a short time, it is still considered to prevent caries. As reported, the combined fluoride toothpaste and mouth rinse results are better than using either alone. The most commonly used fluoride mouth rinse is sodium fluoride mouth rinse. Fluoride mouth rinse is suitable for people with a high risk of dental caries, who are in orthodontic treatment with a fixed appliance, or who cannot care for themselves. Because of its advantages, like low price, easy to master, and convenient to use, it is an excellent choice for school-age children. It is also necessary to read the instructions on using a mouth rinse carefully, mainly when children use it. The fluoride dose should be controlled strictly, and mouth rinses should not be drunk. Therefore, children's compliance needs to be taken into account.

Fluoride varnish

Fluoride varnish has a higher concentration than fluoride toothpaste and mouth rinse. It can be more durable on the surface of the tooth. Fluoride varnish is available in various products, and most of which could be classified into 2.26% fluoride and 0.1% fluoride varnish categories(28). It is used with the dentist's professional judgment and applied in a dental clinic or hospital. After the curing of fluoride varnish, the tooth will discolor temporarily, but brushing the tooth will make the tooth return to its natural color.

Fluoride gel and fluoride foam

Fluoride gel and fluoride foam both have a higher content of fluoride. Acidulated phosphate fluoride (APF) gel or foam is a universal fluoride gel or foam. As for fluoride gel, it contains many kinds of gels with different fluoride concentrations. Some of them can be used by individuals, but professionals use others. The operation method shall be by the direction. Fluoride foam can inhibit the formation of caries. Therefore, the dose of fluoride foam is much less than the same effective concentration of fluoride gel (28).

Conclusions

In conclusion, this theoretical study displayed fluoride various usage in dentistry aiming to protecting teeth and preventing dental decay. It encourages enamel remineralization, reduces glycolysis, and exerts antibacterial effects, specifically against cariogenic bacteria like *Streptococcus mutans*. Fluoride's impact on saliva is also critical, as it keeps a low, constant concentration of fluoride in the oral cavity and preventing dental caries. Moreover, the study focused on the disadvantages and misused of fluoride and consequences toxicity and dental fluorosis. This study indicates that fluoride has important advantages in dental health, but excessive fluoride exposure may lead to dental fluorosis. The authors recommend accurate checking and application of fluoride to balance caries prevention and avoid its toxicity.

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Competing interests statement

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Ethics statement

All authors approved that this research follows the journal's ethical guidelines as appeared on the journal's author guidelines page.

Author contributions

The authors contributed equally to the preparation of this manuscript.

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