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FLUORIDE AND DENTAL HEALTH

Bemhemba IBA, Rapheal Kehinde FALEGBE, Chile IORTYOM, Thelma Ebere NWAOHABUENYI, Yomi Isaac ASA, Ada Cynthia IBEOBI, and Aondover Festus DOGOH

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TABLE OF CONTENTS

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Fluoride and dental health

Iba, B. [1], Falegbe, R. K. [2], Iortyom, C.[1], Nwaohabuenyi, T. E. [4], Asa, Y. I.[3], Ibeobi. A. C. [5], & Dogoh, A. F. [6]

Lead-Author: Mr. Bemhemba Iba *(ibabemhemba@gmail.com)*

[1] *Department of Dental Health, NKST College of Health Technology, Mkar, Gboko, Benue State, Nigeria*
[2] *Department of Dental Technology, Dental Design Laboratory, Lagos, Nigeria*
[3] *Department of Dental Technology, Babcock University Teaching Hospital, Ilishan Remo, Ogun State, Nigeria*
[4] *Department of Dental Therapy, Federal College of Dental Technology and Therapy, Enugu, Nigeria*
[5] *Department of Dental Therapy, Bethel Dental Clinic, Abuja, Nigeria*
[6] *Department of Dental and Maxillofacial Surgery, General Hospital Ifaki, Ekiti State, Nigeria*

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ABSTRACT

Fluoride plays an important role in the prevention of dental caries. Dental caries has remained a global public health concern and is responsible for the highest cause of patient visits to the dental clinic. To review fluoride and dental health, an electronic search of scientific literature was conducted. Database searches were carried out using the terms: "fluoride and oral health", "sources of fluoride", "water fluoridation", "fluoride application", "adverse effects of fluoride", and "functions of fluoride in dental health". There were several works of the literature identified to be related to the subject but only 50 met the inclusion criteria of being published from 2017 to 2021 and they were subsequently reviewed. 32 of the literature reviewed were selected from peer-reviewed journals, 6 from corporate organizations and 12 were articles assessed via Google Scholar. The review observed that fluoride was effective in the control of dental caries and by extension improvement of dental health. However, excessive ingestion of fluoride was responsible for certain side effects, chiefly, dental fluorosis. Therefore, fluoride when delivered appropriately is safe and an effective means of curbing dental caries without any corresponding side effects.

Keywords: *dental caries, fluoride, dental fluorosis, prevention*

INTRODUCTION

Fluoride is the ionic form of the element, fluorine [F^-], which is of the halogen family that includes chlorine, bromine, and iodine. It is the thirteenth most abundant element constituting 0.08% of the Earth's crust and is released naturally into the environment in water, air, soil, plants, and animals. In humans, it could be found in body tissues – mainly in the calcified structures of teeth and bones (Canadian Agency for Drugs and Technologies in Health [CADTH], 2019; Kumar et al., 2017).

Fluoride plays an important role in the prevention of dental caries systemically (pre-eruptive) and topically (post-eruptive). This is achieved through the incorporation of fluoride into the hydroxyapatite crystals of the teeth during tooth formation, which strengthens the teeth, rendering them more resistant to acid attack. During the systemic absorption of fluoride, a little amount of fluoride is deposited into the saliva which helps in promoting remineralization of early carious lesions by replacing the 'OH' in the hydroxyapatite with 'F', which transforms the hydroxyapatite into fluorapatite, thereby enabling the enamel to be more resistant to dental caries. When fluoride is applied topically from toothpaste, mouth rinses, gels, and varnishes, it interferes with the metabolic pathways of bacteria, inhibiting the activities of bacteria in plaque and subsequently inhibiting tooth demineralization (American Academy of Pediatric Dentistry [AAPD], 2020;

Clark et al., 2020; Doumit et al., 2017; Moore et al., 2021; Toumba et al., 2019).

Fluoride can be delivered systemically (through fluoridated water, salt, and milk) or locally (by topical application via toothpaste, gel, varnishes, and mouth rinses). The World Health Organization (WHO) recommends 0.5 mg/L and 1.0 mg/L as the acceptable limits for fluoride (safe) in drinking water though a maximum dose of 1.5 mg/L is still acceptable by WHO. The Nigerian Standards for Drinking Water Quality pegs the optimal permissible fluoride concentration at 1.5 mg/L. This is sufficient enough to prevent dental caries and protect against the risk of dental fluorosis arising due to excessive fluoride exposure (Akuno et al., 2019; Ani et al., 2021; Giwa et al., 2021; Ichu & Agulana, 2018; Orakpoghenor et al., 2021).

In toothpaste, the concentration of fluoride recommended by the Standards Organization of Nigeria (SON) and the National Agency for Food and Drug Administration and Control (NAFDAC) is 825-1250 part per million (ppm) while the Nigerian Dental Association (NDA) pegs the recommended figure at 950-1500 ppm (Kpalap et al., 2021; Owoseye, 2019).

The prevalence of dental caries has continued to surge in developing countries ("Field Observation", 2021). With this in mind, it is imperative to assess fluoride and dental health so as to inform dental caries preventive strategies more effectively. This review is focused on discussing published information from recent peer-reviewed journals and other materials (2017 to 2021) concerning the history, sources, metabolism, functions, application, and harmful effects of fluoride as they relate to dental health.

BRIEF HISTORY OF FLUORIDE

In 1901, Dr. Frederick McKay, a young dental graduate started his dental practice in Colorado Springs, U.S.A, where he noticed that almost 90% of his patients had mysterious brown staining of their teeth. He invited Dr. G. V. Black and collaborated with him in conducting studies to unravel the cause of this phenomenon. They discovered through their studies that the staining observed from Colorado city patients was a result of imperfections in the development of the tooth enamel. Another notable observation they made that stunned them was that individuals affected by the staining were decay-free. Dr. McKay had to probe further to discover that there was something inside the source of drinking water that was responsible for the staining. It was not until the early 1930s that other scientists identified the culprit as fluoride (Bibbs, 2017; Children Dental Centre, 2018; Doumit et al., 2017; Littletoothco, 2021; Steiner, 2020; Unde et al., 2018; Zelko, 2018).

SOURCES OF FLUORIDE

Fluoride occurs in small amounts in animals, plants, and some natural water sources. It can be ingested from several sources such as foods, fluoridated and unfluoridated water, fluoridated toothpaste, and some dietary supplements (Kpalap et al., 2021). There are two major sources of fluoride: natural and anthropogenic (Kumar, 2017; Naik et al., 2017).

Natural sources of fluoride

A. **Water**: water is the main source of fluoride intake available to human beings, plants, and animals. The level of fluoride in groundwater is higher when compared to surface water. This is because fluoride percolates from the soil into groundwater through leaching. Geological factors, soil consistency, nature of rocks, temperature and pH of the soil, depth of wells, chemical and physical characteristics of water, shallow groundwater leakages, and chelating action of other elements are some of the factors responsible for the presence of fluoride in natural groundwater (Onipe et al., 2020).

B. **Soil**: Soil fills in as a fundamental capacity in nature, giving a medium to establish development and supplements for plants. Soil is a fundamental factor that controls the nature of water. The fluoride content of soil goes from 150-400 mg/kg. The fluoride level in the earth's soil is 1000 mg/kg. Fluoride contaminates the soil as a result of the usage of phosphorus manures which have all-out 1-1.5% fluorine. Soil that is polluted with fluoride shows its poisonousness after the inward breath of soil pollutants which have vaporized or through the sullied groundwater after the fluoride has drained from the dirt (Bharti et al., 2017).

C. **Food**: fluoride occurs naturally in different places and food is no exception. Several foods consumed by man are rich in fluoride. Examples are spinach (0.07 mg of fluoride), grape, raisin, wine (fluoride per 200 Calories: 369.4 µg), black tea, potatoes (0.49 ppm of fluoride) (National Institutes of Health {NIH}, 2021; Satou et al., 2021).

D. **Volcanic activities**: during a volcanic eruption, fluoride is released in the form of hydrogen fluoride which covers several places and remains for a long period. Over time, fluoride undergoes leaching and decomposition and causes adverse effects to domestic and wild animals and humans (Linhares et al., 2019).

Anthropogenic sources of fluoride

Human activities like motorization, industrialization, pesticides containing fluoride, water fluoridation for public consumption, dental products, fire extinguishers, and refrigerants are the major anthropogenic sources of fluoride contamination. Coal-burning for household purposes, utilization of chemicals like calcium fluoride, hydrogen fluoride, sodium fluoride, and phosphate manures are other sources of fluoride under the anthropogenic category (Bharti et al., 2017).

FLUORIDE METABOLISM AND DISTRIBUTION

Fluoride is an element that occurs naturally on the surface of the earth. It is the most abundant electro-negative element capable of reacting with other known elements except helium and neon. Fluoride-containing compounds are very different. For that reason, it is absurd to expect to sum up on their digestion, which relies upon their reactivity and design, solvency, and capacity to deliver fluoride particles (Bharti et al., 2017; Kabir et al., 2020).

Fluorine is found in an inorganic state with a cariostatic effect which lends credence to the implementation of fluoride in the body and plays a vital role in bone mineralization and the formation of dental enamel. Knowledge of fluoride metabolism is of great importance – not only to understand its biological effects but also to enhance fluoride-driven preventive and therapeutic strategies. Fluoride is widely used for the control of dental caries, but increased intake can affect both hard and soft tissues negatively, with dental fluorosis being the most prevalent negative effect. Fluoride metabolism is affected by any systemic, metabolic, and genetic alteration (Kumar et al., 2017).

The metabolism of fluoride is constituted of several processes; absorption, secretion, distribution, and excretion.

Absorption of fluoride

Fluoride enters the body through the gastrointestinal tract and is absorbed in the stomach. Fluoride absorption relies upon various factors such as stomach pH and solubility of the ingested fluoride compound. Sodium fluoride and hydrogen fluoride which are more soluble compounds are absorbed faster as compared to magnesium and calcium fluoride that are less soluble. (Ullah et al., 2017).

Plasma levels increase (at 10 minutes) as soon as fluoride is absorbed, reaching peak levels at 60 minutes. Once fluoride reaches the plasma, it is deposited rapidly in the skeleton or excreted through the kidney (Kumar et al., 2017)

Secretion of fluoride

Fluoride is secreted in saliva. With an increase in salivary levels, the plasma levels also increase by the same proportion. Despite salivary levels being within the range of 0.01 to 0.06 ppm for individuals exposed to fluoride, their important role in dental caries prevention cannot be underestimated (Kumar et al., 2017).

Distribution of fluoride

The concentration of fluoride in the teeth and skeleton is higher when compared with other tissues and structures, the teeth and skeleton have the highest concentrations of fluoride because of the affinity of fluoride for calcium. In descending order, the highest levels are found in cementum, bone, dentin, and enamel. The fluoride content of teeth and bones increases rapidly during the early mineralization periods and continues to increase with age, but at a slower rate. Once deposited, it is firmly bound to the tooth mineral for life. Fluoride interaction in the oral cavity is interesting as it provokes a comprehensive appreciation of the dental caries formation process. It forms the elements of the interaction between the oral fluids and the dental hard tissues (Demelash et al., 2019; Malago et al., 2017).

Dental caries can only occur if some basic factors are present such as debris accumulation on the teeth, refined carbohydrates, and bacteria over time. Fluoride will physicochemically initiate mineral precipitation on the tooth structure as fluorapatite; this can occur while demineralization is happening inside the biofilm milieu (an impact called decrease of demineralization), or after acids have been cleared from the biofilm or the biofilm itself was taken out (the purported improvement of remineralization). Thus, fluoride kept on the tooth mineral should be viewed as a result of diminished mineral misfortune happening within the sight of fluoride, and not the objective of its preventive activity (Sun et al., 2020; Villa et al., 2018).

Excretion of fluoride

The principal route of excretion (90 to 95%) of fluoride is in the urine. It is the most essential metabolic pathway to get rid of fluoride in the body. The remaining 5 to 10% of fluoride is excreted via faeces while sweat also contributes to the removal of little amounts of fluoride from the body system (Green et al., 2020).

FUNCTIONS OF FLUORIDE IN DENTAL HEALTH

Dental caries has remained a global public health concern in the 21st century. An estimated 486 million children worldwide suffer from caries of primary dentition while 2.4 billion people suffer caries of permanent dentition (WHO, 2019).

Studies in Nigeria have proven that fluoride when consumed in the long term at the recommended levels is effective in the prevention of dental caries (Ani et al., 2020; Ichu & Agulana, 2018).

According to Ani et al. (2020) and Ichu & Agulana (2018), the different actions taken by fluoride to control the effects of dental caries on the dentition are highlighted thus:

i. The presence of fluoride in saliva and dental plaque at constant and low concentration delays the demineralization of the tooth and subsequently hastens the remineralization of the tooth enamel lesion.

ii. Fluoride interferes with glycolysis, the cellular degradation of simple sugar glucose to produce acid. This is achieved by lowering the surface energy of the tooth, thereby making it difficult for plaque formation and bacteria attachment.

iii. Fluoride increases the enamel's resistance to acid solubility as a result of the high concentration of fluoride on the enamel. This is because fluoride is less soluble in acid and less likely to develop caries. It replaces the hydroxyl in the hydroxyapatite lattice with fluoride ion making it more stable and less soluble.

APPLICATION OF FLUORIDE

There are two ways of fluoride application, namely, topical and systemic application.

Topical application

The topical application of fluoride involves applying fluoride directly on the surface of the tooth. It could be self-applied or applied by a professional.

Self-applied topical fluorides

a) Fluoride toothpaste: it is the simplest and most commonly used form of self-applied fluoride worldwide. About 90% of the different toothpaste sold in the market contain fluoride that is applied to prevent caries and improve oral health. Fluoride toothpaste is cheap, convenient, and of different choices. The concentration acceptable for use is 1000-1500 ppm of fluoride per gram of toothpaste while a reduced dose of 100-550 ppm is recommended for children (American

Dental Association [ADA], 2021; Doumit et al, 2017; Sun et al, 2020; Whelton et al, 2019).

b) Fluoride mouth-rinse or gels: it is a concentrated solution meant for daily or weekly use designed for rinsing and spitting out. Sodium fluoride is the most common fluoride compound used in mouth-rinse and it is retained in dental plaque and saliva to help prevent dental caries. 230 ppm fluoride (0.05%) is recommended for daily rinsing by persons older than 6 years while for those less than 6 years, this is not recommended because of the risk of fluorosis should it be swallowed repeatedly (ADA, 2021; Do, 2019; National Health Service {NHS}, 2021).

Professionally applied topical fluorides

I. Fluoride mouth-rinse, gels, or foams: these fluorides come in form of gels, foam, or rinse and they are applied by a dental professional in the course of a dental visit. Since they are not frequently applied, their concentration is higher as compared to the self-applied fluorides. Some of the products include acidulated phosphate fluoride gel (12,300 ppm), neutral sodium fluoride (9,000 ppm), and foams of sodium fluoride (9,040 ppm). These professionally applied fluoride gels are only beneficial to persons at high risk of tooth decay especially among those who do not consume fluoridated water and practice brushing without fluoride toothpaste (ADA, 2021; Do, 2019).

II. Fluoride containing prophylaxis paste: it is used during oral prophylaxis and is a very abrasive paste that contains 4,000-20,000 ppm fluoride. It is used once every 6 months to restore the concentration of the surface layer of the enamel (Sun et al., 2020).

III. Fluoride varnish: it is available as sodium fluoride (2.26% fluoride) or difluorsilane (0.1% fluoride). It is used with professional judgment from the dental practitioner and applied in the dental clinic. Fluoride varnishes are more durable on the surfaces of the tooth (Dalal et al., 2019)

Systemic Application

These fluorides provide both systemic and topical protection to the tooth. They include water fluoridation, salt fluoridation, milk fluoridation, and fluoride tablets.

Water fluoridation

Community water fluoridation is the practice of adjusting the amount of fluoride in the water supply to achieve an optimal concentration that will be effective in the prevention of dental caries. The fluoride concentration of water that is suitable for community water fluoridation is between 0.5-1.1 mg/L (Clark et al., 2020; Toumba et al., 2019).

Community water fluoridation is beneficial to all residents within a community not minding their socio-economic status, level of education, age, oral hygiene practices, access to routine dental care, or employment, making it a public health practice that is truly equitable. It has the advantage of being a safe, cost-effective means of delivering caries prevention to a large population, consistent, and having a low over-dosage risk (Bharti et al., 2017; Doumit et al., 2017).

Fluoridated milk

Studies have indicated that milk which is an essential food for children is used as a vehicle for fluoride administration. Fluoridated milk has been proven to be an effective means of caries reduction like fluoridated water. It contains nutrients that help to buffer acid thereby reducing the risk of dental caries after consumption of a sugary beverage. It however has a shortcoming of being difficult to control (Aoun et al., 2018).

Fluoridated salt

Salt fluoridation is the addition of fluoride into salt which when consumed, becomes absorbed into the body. The fluoridation of salt is an effective means of caries reduction, especially in areas where fluoridation of water is not feasible. Salt fluoridation is very effective; however, the promotion of salt consumption to benefit oral health would contradict the desired reduction of salt consumption to prevent hypertension. The recommended dose is 250 ppm (Doumit et al., 2017).

Fluoride tablets

It is prescribed for children between 6 months to 16 years of age who live in areas with low content of fluoride. Tablets and lozenges are manufactured to contain sodium fluoride as an active ingredient to be chewed or sucked for 1-2 minutes before being swallowed. The dosage for children under the age of 4 years is 0.5 mg fluoride/mg and 0.75-1 mg for older children. The prescription should be given by a dentist (Doumit et al., 2017; Sun et al., 2020).

HARMFUL EFFECTS OF FLUORIDES

Despite the benefits of fluoride to dental health and the important role it plays in caries prevention, excessive intake of fluoride can produce varying effects depending on the amount of exposure and duration it occurs. Chronic high intake of fluoride affects teeth and bones while acute consumption of large amounts has serious side effects and could be life-threatening.

Fluorosis: Dental fluorosis is a developmental disturbance of the enamel which occurs during the formation of the enamel. It is caused by the excessive exposure of the teeth to fluoride during childhood. It is the most frequently seen and most reliable sign of systemic overexposure to fluoride in drinking water. It is characterized by the appearance of tiny streaks or specks on the enamel of the tooth in its mildest or most common form while in severe cases, it appears as white mottled patches, brittle and brown colouration, pitted and rough enamel (Brazier, 2018; Frisbee, 2021; Kumar et al., 2017; Moawad, 2020; Sun et al., 2020).

Fluorides combine to form calcium fluorapatite to replace part of the hydroxyapatite. When the concentration becomes too high, it damages the ameloblast leading to defective matrix formation. At intermediate levels between 2-6 ppm, the matrix is normal in structure and quantity though with patches indicating the incomplete calcification under the surface layer. Where the fluoride concentration is at high levels above 6 ppm, the enamel is pitted and brittle with severe and widespread staining (Abdullatef, 2018; ADA, 2021; Idon & Enabulele, 2020).

Teeth with fluorosis are generally resistant to dental caries except for most severe cases but discoloration may be noticeable which is of cosmetic concern. Primary teeth are less likely to develop fluorosis because excess fluoride is taken up by the maternal skeleton. However, in cases where the fluoride levels exceed 8 ppm, mottling may be present in primary teeth as well (Femi-Akinlosotu et al., 2021; Kumar et al., 2020; Neurath et al., 2019).

Studies across Nigeria have also observed that excess fluoride in water can result in dental fluorosis as evident in the study among residents in some communities within Gombe State, Nigeria. It was observed that 38% of the population of a certain community had dental fluorosis, 27% had skeletal fluorosis, 22% had dental and skeletal fluorosis and 13% were without fluorosis. The fluoride concentration in their water was 2.4 mg/L {2.4 ppm} (Giwa et al., 2021).

Acute toxicity of fluoride can occur as a result of over ingestion of one or more doses of fluoride over a short period which could lead to fluoride poisoning. Early signs and symptoms include nausea, abdominal pain, vomiting, and diarrhea. Shallow breathing, paleness, weak heart sounds, cold skin, and dilated pupils could follow. Other effects such as skeletal fluorosis, bone fracture, muscle paralysis, extremity spasm, and carpopedal spasm could be possible. Despite the widespread presence of fluoride, it is very rare to have acute cases of fluoride toxicity (Chatterjee et al., 2020; Orakpoghanor et al., 2021).

CONCLUSION

The prevalence of dental caries has declined with oral hygiene awareness and the improvement of dental services in developed nations. It is appalling that the opposite is the case for developing countries especially in Sub-Saharan Africa where cases have continued to surge. Studies on the use of fluoride in the prevention of dental caries have yielded positive results over the years. Fluoride when delivered appropriately either systemically or topically is considered safe and an effective strategy to contain caries at the community or individual level.

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Authors' OrCID iDs:

[1] Iba, B.:	0000-0001-5519-5050
[2] Falegbe, R. K.:	0000-0002-5238-96150
[1] Iortyom, C.:	0000-0002-9288-4768
[4] Nwaohabuenyi, T. E.:	0000-0003-0457-248X
[3] Asa, Y. I.:	0000-0003-4846-5395
[5] Ibeobi. A. C.:	0000-0003-2086-4861
[6] Dogoh, A. F.:	0000-0002-7350-0490

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