2018

Cultural and Environmental Determinants of Dental Discoloration Among School-Aged Children in Nigeria

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Abstract

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MPH, Ahmadu Bello University, Zaria; Nigeria, 2009

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Dissertation Submitted in Partial Fulfillment

of the Requirements for the Degree of

Doctor of Philosophy

Public Health, Epidemiology

Walden University

February 2018

Abstract

Dental discoloration from fluorosis is a global public health problem. In Nigeria, 11.4% of the population is impacted by this disorder. Dental discoloration is caused by successive exposures to high fluoride concentrations during tooth development in utero and it is linked to the development of a variety of psychological and physiological problems, from dental aesthetics to a reduction in intelligence and skeletal changes. The purpose of this quantitative, cross-sectional study was to examine the cultural and environmental determinants of dental fluorosis in children in a rural community in Nigeria. A multilevel theoretical model was used to develop possible fluoride exposure pathways, such as good social services and dental care, as well as factors in the environment. The study was guided by 2 main research questions: What is the prevalence of fluorosis among Nigerian school-aged children? What is the severity of this fluorosis, and is it associated with the fluoride content of the soil, the water or the food? Data was collected by administering three surveys, on children aged 5 to15 years, their parent/guardian, and on community leaders. Chi-square and regression analysis tests were used to test for possible associations. The study findings showed a fluorosis prevalence rate of 86.6% in the 269 school children surveyed, with majority of these children between the ages of 8 to 13 years. The severity of children fluorosis was associated with the length of stay in the study area and the fluoride content in water, soil, and food. This study's possible impact on social change include raising awareness to the problem and the possible ways to resolve it, such as through, improved dental care services and a supportive social environment like flocculation of community water sources.

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Dedication

I wish to dedicate this work to my family, especially my wife Angela, for her unrelenting support and understanding of the challenges I have faced during this phase of my studies. I appreciate your inspiring encouragement and hard work that enable me to undertake this program.

Acknowledgments

I wish to firstly acknowledge the immense contribution made by my dissertation chair, Professor Amany Refaat, to see me through this dissertation process. I know how much of a headache I have caused her. I also wish to thank my initial committee member, Dr. Shipps, for her very critical and intense guidance on the methodology section which appropriately helped improve the quality of the work. I also wish to thank the IRB team for providing me with all necessary assistance to achieve my study goals. I have also benefitted greatly from the contributions of my second committee member Dr Donald Goodwin who helped with further corrections to my methodology and result section. I am also grateful for the comments by my University reviewer Dr Frazier Benjamin and the exposure provided by the Faculty of health sciences and the faculty members in the public health program for their gradual but sure guidance during my studies.

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Chapter 1: Introduction to the Study

Introduction

Dental discoloration is a growing public health problem that affects the quality of oral health in developing countries. Koleoso, Shaba, and Ishiekwe (2004) estimated that the prevalence of intrinsic tooth discoloration among 11 – 16 - year - old Nigerians was 36% for boys and 39.5% for girls; the most common types of intrinsic tooth discoloration are enamel opacities, tetracycline staining, and enamel hypoplasia. Other causes include dental caries, pulp necrosis/hemorrhage, tooth wear, and discolored restrictions (such as used in tooth alignment). Similarly, Alvarez et al., (2009) and Kerr et al.,(2011) found that common risk factors for tooth discoloration included dental fluorosis caused by successive exposures to high concentrations of fluoride during tooth development (daily recommended intake: 0.05 to 0.07 mg/f/kg), poor oral hygiene, exposure to metallic compounds, topical medications (such as chlorhexidine rinse) and indiscriminate use of tetracycline drugs.

Generally, tooth discoloration is said to have occurred when there is a deviation in tooth color. Suresh and Gopi (2010) noted that the normal color of primary teeth is bluish white, whereas the color of permanent teeth is grayish white or yellowish white. They also noted that this color is determined by translucency, thickness of the enamel, and color of the dentin and pulp, and that changes in color could be due to physiological, pathological, or exogenous/endogenous causes. The teeth of adults usually appear more yellow or grayish yellow than those of younger persons because as one ages, the enamel becomes thinner from erosion, while the dentin becomes thicker from the deposition of secondary dentin. However, the major cause of tooth discoloration is decomposition of pulp tissue, which is the first indication that the pulp is dead; (Suresh & Gopi, 2010).

Types of Tooth Discoloration

There are two types of tooth discoloration, extrinsic and intrinsic. While the extrinsic type is apparent on the outer surface of the teeth, the intrinsic type stains are within the dentin enamel, a problem that appears during the development of the tooth. The Nathoo (1997) classification system for extrinsic dentin stains include three categories: (a) Nathoo type 1 (N1) comprises colored material (chromogen) that binds to the tooth surface. The colors can be similar to stains produced by tea, coffee, wine, chromogenic bacteria, and metals; (b) Nathoo type 2 (N2) comprises colored material that alters its color after binding to the tooth surface. Usually, these stains are N1-type food stains that darken with time; and (c) Nathoo type 3 (N3) includes colorless materials that, upon binding to the tooth surface, undergo a chemical reaction to cause a stain. N3-type stains are caused by carbohydrate rich foods (e.g., apples and potatoes), stannous fluoride, and chlorhexidine.

Some causes of extrinsic dental discoloration include tea, coffee, tobacco smoking/chewing, betel nut chewing, drugs (e.g., chlorhexidine mouth rinse), iron salts, heavy metals (e.g., silver nitrate and lead), essential oils, amoxicillin-clavulinic acid, ciprofloxacin, linezolide, and glibenclamide (Kumar, Kumar, Singh, Hooda and Dutta, 2012).

Factors that predispose children and adults to extrinsic tooth discoloration include enamel defects, salivary dysfunction, and poor oral hygiene. Small pits and defects on the outer surface of the enamel can lead to an accumulation of food particles and stains from beverages, tobacco and other topical agents (Patel et al., 2013) and predispose a person to tooth discoloration. Salivary dysfunction such as, decreased salivation can lead to difficulties in removing food debris from the tooth surface and can thus contribute to the staining of teeth. Conditions that are associated with a reduction in salivation are salivary gland obstruction and infection, Sjögren syndrome, head and neck radiation therapy for cancer, chemotherapy, and multiple medications (e.g., anticholinergics, antihypertensive, antipsychotics and antihistamines): All of these can cause tooth discoloration (Patel et al., 2013). However, the most common cause of dental discoloration is poor oral hygiene. It is important to note that dental discoloration from extrinsic causes are considered to be distinct from intrinsic causes (Patel et al., 2013).

According to Patel et al., (2013), intrinsic causes of tooth discoloration arise from either pre-eruptive or post-eruptive processes or from a deviation in normal tooth formation. Some of the causes of intrinsic tooth discoloration include, dental materials used for dental restorations (e.g., amalgam restorations can generate corrosion products such as silver sulfide) which can leave a gray-black color on the teeth. Other conditions include dental caries; trauma; infections; and medications such as tetracycline, minocycline and doxycycline. These medications can leave a characteristic bright-yellow band that fluoresces under ultraviolet light (tetracycline) or a green-gray or blue-gray intrinsic staining (minocycline). Another element, fluorine, causes enamel discoloration through hypomineralization when too much fluoride is ingested during the early maturation stage of enamel formation (Patel et al., 2013); dental discoloration from fluorosis comes with a wide range of clinical findings.

There are still other causes of intrinsic tooth discoloration, which include nutritional deficiencies, such as vitamin C, vitamin D, calcium, and phosphate - all are required for healthy tooth formation. Deficiency may lead to enamel hypoplasia. Diseases that may cause intrinsic tooth discoloration include sickle cell anemia, thalassemia, hemolytic disease of newborns due to either Rhesus factor ABO or other erythrocyte antigen incompatibilities, and biliary atresia (Patel et al., 2013). These diseases can cause hyperbilirubinemia, producing a jaundice-like yellow-green tint on the tooth surface. Genetic defects and hereditary disease can also lead to intrinsic tooth discoloration. Such genetic defects that lead to abnormal enamel or dentin formation include amelogenesis imperfecta, dentinogenesis imperfecta, and dentinal dysplasia. Other hereditary diseases include erythropoietic (congenital) porphyria and epidermolysis bullosa. In these disease, the entire primary and secondary dentitions are pink (Patel et al., 2013).

Dental Fluorosis

In the preceding section I listed several factors associated with both extrinsic and intrinsic tooth discoloration. This was meant to provide the understanding about the different causes and types of tooth discoloration, as well as how it develops. Here, however, the focus is on human fluorosis, namely how it develops and how it affects children. Dental fluorosis, also called mottled enamel, is a term used to describe the hypoplasia or hypomineralization of tooth enamel caused by excessive ingestion of fluorine. Ando et al., (2001) reported that fluorosis in humans arises from the intake of fluorine through drinking water. Only in rare occasions is high fluorine intake caused by fluoride-rich vegetables due to a natural accumulation (such as from soil with high fluoride content) or anthropogenic contamination (such as from environment contaminated with high fluoride e.g. volcanic eruptions or phosphates producing plants).

Furthermore, various practices and natural occurrences have been associated with the development of fluorosis. For example, Kerr et al. (2011) noted that the fluoride concentration of naturally fluoridated water varies depending on geographic location. In some areas in Africa, the concentration in these natural waters is as high as 10ppm compared to artificially fluoridated waters which is usually controlled at 1ppm. This high fluoride content is said to derive from either water-rock interaction (WRI) processes in volcanic aquifers (ground waters) or from contamination of surface waters by magnetic fluorine from volcanoes (Kawahara, 1971). WRI processes increase with elevated temperatures and/or strong acidic conditions (Aiuppa, D'Alessandro, Federico, Palumbo & Valenza, 2003). Researchers from the University of California, and the University of Addis Ababa, noted that the high fluoride levels in naturally occurring African groundwater places the oral health of about 80 million people living in the main Ethiopian Rift Valley at risk (Kloos & Haimont, 1999).

Cultural practices that could involve the use of water from highly fluoridated sources include drinking and cooking and, the use of clay pots made from soil extracted from riverbeds and lakebeds that have high fluoride content. Economic factors - such as poverty, inaccessibility to municipal water supplies and lack of knowledge - may contribute to tooth fluorosis. Generally, poverty is said to predispose people to fluorosis because of its association with a low intake of protein, calcium, and vitamin C and D, all of which increase the risk of dental fluorosis when the intake is too low (Nanyaro, Aswathanayana, Mungure, & Lahermo, 1984; Qian, Susheela, Mudgal & Keast, 1999).

These findings are in agreement with the observations by Allen (2003), who assessed oral quality of life and noted that there is an observable difference in tooth loss across various communities; this may suggest a cultural and economic influence on oral health outcomes. These observable differences may be due to cultural practices involving the use of water, but economic factors affect the quality of water available in the communities. Biazevic et al. (2004) assessed the impact of oral health conditions on the quality of life. Using the Oral Health Impact Profile as a measurement tool for a group of 183 elderly people, they observed a correlation between socioeconomic (SES) position, such as formal education and number of residents per household, to the quality of oral health.

However, while we are aware of the many risk factors for the development of dental discoloration in general, we do not know how early exposure to cultural practices in these communities (e.g., the use of naturally flowing waters and, cooking with clay pots and foods), can affect the development of dental fluorosis in children (thus leaving a gap in the literature). The study by Biazevic et al. (2004) that established a correlation between dental discoloration with SES position and number of residents in households used an adult population as their sample which is different from my study.

Mechanism for the Development of Fluorosis in Children and Mineralization of Permanent Dentition

Normally, fluorine is an essential element in the development of the mineral content of bones and teeth in the form of fluoroapatite (World Health Organization [WHO], 2002). However, physiologically, permanent dentition begins to form in utero and mineralization is usually complete by 4 or 5 years of age and root development by 2 to 3 years after eruption (Kumar et al., 2012). Thus, during mineralization, teeth are prone to developmental disturbances and permanent dentition could become more susceptible to disturbances in mineralization by drugs and environmental toxicants (Billings, Berkowitz, & Watson, 2004). Such disturbances include high fluoride levels above those recommended by WHO, which recommends the maximum limit of fluoride in drinking water to be 1.5 mg/l and further recommends a lower limit of 1.0 mg/l in hotter climates because of higher amounts of water ingested (WHO, 2002).

As previously stated, fluorosis in children begins with the interference of fluoride with the process of enamel formation and maturation in utero. It is speculated to (a) affect the maturation of ameloblasts by influencing their ability to remove protein and water from maturing enamel and/or (b) interfere with the ameloblasts' capacity to produce the proteolytic enzymes necessary to initiate amelogenin breakdown (Fejerskov, Manji, & Baelum, 1990). According to Den-Besten's dairy (as cited in Kumar et al., 2012), the delay in hydrolysis of amelogenin could be due (a) to a direct effect of fluoride on proteinase secretion or proteolytic activity or (b) to a reduced effectiveness of the proteinase because of other changes in the protein or mineral of the fluorosed enamel matrix.

The Health Implications of Fluorosis

The significance of this study lies in seeking to ameliorate the damage caused by the adverse health effects that impact those exposed to fluorosis. These effects range from aesthetic to psychological; decreased intelligence; skeletal fluorosis as children grow older; and, finally, overall poor quality of life (Aguilar-Diaz, Irigoyen-Camacho, & Borges-Yanez, 2011). The importance of aesthetic concerns from dental fluorosis was shown in two studies; they showed that aesthetics of the teeth is a cause for concern in about 2.1% to 3.3% of children with mild fluorosis in fluoridated areas (Saravanan et al., 2008; Laurence, Lewis, Dixon, Redmayne & Blinkhorn, 2012).

Regarding overall well-being and oral health-related quality of life, a study by Aguilar-Diaz, et al. (2011) conducted among 212 school-aged children (ages 8 to 10 years) in the north-central area of Mexico found that 51.6% of the children perceived that the condition of their mouths affected their quality of life. It should be noted that, the children with dental fluorosis had high scores in all domains of children's perceptions about their quality of life (Aguilar et al., 2011).

Of greater concern however, is the effect of fluorosis on the mental development of children. As noted by Saxena, Sahay and Goel (2012), there is an observable reduction in intelligence in children exposed to increased water fluoride levels. Thus, children in endemic areas of fluorosis are at risk for impaired development of intelligence (Saxena et al., 2012).

Another health effect of early exposure to fluorosis is the development of skeletal fluorosis as children grow older (Cao et al., 1996). Among Tibetans who experience early exposure to fluorosis through the intake of high fluoride in their tea, the detectable rate of skeletal fluorosis was found to increase with age, especially after age 30. For Tibetans over 40 years of age, this rate is about 50% of the total population (Cao et al., 1996). Some major disorders related to cases of skeletal fluorosis include osteoporosis, radial collateral interosseous membrane ossificational hyperplasia, narrow joint space, and cystic degeneration under the articular surface. Ulnar and radial collateral interosseous membrane ossificational hyperplasia is a specific change caused by skeletal fluorosis and is said to be detectable in about 87% of cases (Cao et al., 1996).

All these concerns are of immense significance in relation to the health status of a population in endemic fluorosis regions and it is important that steps should be taken to address this problem (Cao et al., 1996). Thus the social change implications of this study involve helping to address the disabilities, disease and loss of resources (dollars) that could arise from the problems associated with fluorosis. Although fluorosis does not cause death, the associated disabilities due to reductions in intelligence, the psychological effects caused by aesthetics of the teeth, and the limitations in mobility caused by the development of skeletal fluorosis, lead to many lost hours of human resources and finances - all of which are associated with a low quality of life.

Background

In 1948, the WHO defined health as "state of complete physical, mental and social wellbeing and not necessarily the absence of disease or infirmity" (Park, 2005, p.705). This study investigated the environmental and cultural practices that predispose children of the Mumuye community in rural Nigeria to the development of dental discoloration. Previous studies (Cao, Zhao, & Liu, 1997; Kahama, Kariuki, Kariuki, & Njenga, 1997; Pandey & Pandey, 2011) linked various factors to the development of dental discoloration in children. One of these studies (Cao et al., 1997) attributed dental discoloration to dental fluorosis in children due to exposure to high concentrations of fluoride in food. This study by Cao et al. (1997) was conducted in the Ganzu province of China; the study was able to link the tradition of drinking milk tea made with brick tea water to excess fluorine consumption. A similar study (Kahama et al., 1997) conducted in the Rift Valley of Kenya, an area with intense volcanic activity, linked the development of dental fluorosis to the high fluoride content in the naturally flowing community water supply and foods grown in soil in this region. Similarly a study by Pandey and Pandey (2011) indicated that industrial activities, particularly phosphate fertilizer factories, aluminum factories and glass fiber factories, can produce air-borne fluoride in their vicinities and that the inhalation of such air-borne fluoride could significantly enhance human exposure (Pandey & Pandey, 2011). These authors also demonstrated that air-borne fluoride generated from such industrial activities was the major factor for a higher prevalence of fluorosis in the rural areas of India where these activities were taking place, thereby linking environmental exposure to elemental fluorine to the development of fluorosis.

Furthermore, it was suggested that high altitudes exacerbate dental fluorosis especially among children (Cao et al., 1997). These authors reviewed studies from other researchers (Allison, Devine, Mahar, & Angmar-Mansson, 1983; Whitford & Angmar-Mansson, 1995; Zhang et al., 1995) and noted that under conditions of a lack of oxygen, rats take up more fluoride and the growth of enamel is unfavorably affected. They also noted that reduced air pressure can change the balance of the metabolism of fluoride and calcium. All of these situations may exacerbate dental fluorosis in children living or working, such as cropping, in regions with high altitudes.

Problem Statement

Information on how cultural and environmental practices lead to dental discoloration (e.g., cooking methods, water type, and climate) is sparse and has been difficult to access. While some research has been carried out in other aspects of dentistry, such as dental trauma (Wendt et al., 2010, Altun et al., 2009), little has been done on environmental and cultural practices that are associated with dental fluorosis in Nigeria. The current study is beneficial–especially to communities where there is a high fluoride content-because it can create awareness about the psychological and social impacts associated with dental discoloration caused by fluorosis.

Generally, studies that found a correlation between high fluoride content in water and food with dental fluorosis in children were conducted on high plateaus or deserts, such as in north-east China, where the practice of drinking brick tea water is well established (Cao et al., 1997). In East Africa, however, the study population for this study was drawn from communities around the Rift Valley in Kenya, where faulting and volcanic activity have been intense (Kahama et al., 1997). These activities may account for the high fluoride content of the soil. However, no attention has been paid to cultural practices in areas where there is no volcanic activity or where the altitude is not high. Thus, this type of community is the focus of the present study.

The study by Malde, Scheidegger, Julshamn and Bade (2011) on substance flow analysis of fluoride exposure through food and beverages in young children living around the Ethiopian Rift Valley, noted that high amounts of fluoride were retained in food prepared with water containing high fluoride levels (Malde et al., 2011). The study also identified sources of fluoride to include staple food items such as *injera,* which is made from teff, a grain from the *Eragrostis tefl abyssinica* grass. Injera is an unleavened bread prepared by fermenting teff, wheat, barley, maize, sorghum or a mixture of these grains. However, the findings from this study cannot be generalized to other cultures such as

Nigeria, because of the different climate and food cultures. Thus it was important that this study be carried out to fill current gaps in knowledge on dental fluorosis.

Purpose of the Study

The purpose of this quantitative, cross-sectional study was to examine the cultural and environmental determinants of dental fluorosis among children in the Zing local government area, a rural settlement in northern Nigeria. This area belongs to the Mumuye tribe of Taraba State, in north-east Nigeria, whose population is commonly associated with discolored teeth right from childhood (Ambinkanme, Sale, Ahmed, Peters & Magaji, 2014). The tribe lives on a fairly hilly terrain with a warm climate and a few naturally flowing streams running through different sections of the community (Taraba State, 2012). The community does not have a municipal water supply and therefore depends on water from streams and some boreholes. The major occupation of the local inhabitants is subsistence farming (Ambinkanme et al., 2014). Some of the cultural and environmental practices in the community include the use of clay pots for cooking and storing water; the use of water from open streams for household chores; consumption of dawa (form of millet), bambara nuts and the yam tuber as staples; cultivation of land to grow grains; and the use of fertilizers to enhance agricultural yield (Ambinkanne et al., 2014). Zing has 92 public primary schools, 12 junior secondary schools, 9 senior secondary schools and 1tertiary school (Taraba State, Directory of Schools, 2014). As previously stated, the intention of this study was to ascertain to what extent the exposure to environmental and cultural practices (such as water use and storage in the community, the soil that foods are cultivated in, types of food eaten and cooking methods) contribute to the development of dental fluorosis in children ages 5 to 15 years.

The independent variables examined in the study were the fluoride content of the community water supply, common foods, and the soil. These three were studied to see how they were associated with the development of dental fluorosis in children as the dependent variable. The possible covariables examined in the study included cooking with clay pots and SES.

Research Question(s) and Hypotheses.

Research Questions

The research questions for the study were the following:

1. What is the prevalence of dental fluorosis in children ages 5 to 15 years in the Zing community?

   H_0^1 Null hypothesis: The prevalence of dental fluorosis in children ages 5 to 15 years in the Zing community is negligible.

   H_A^1 Alternative hypothesis: The prevalence of dental fluorosis in children ages 5 to 15 years in the Zing community is significantly high.

2. Is there an association between the presence of fluorosis among children in the Zing community and dawa consumption by these children?

   H_0^1 Null hypothesis: There is no association between dental fluorosis in children and consumption of dawa by these children.

   H_A^1Alternative hypothesis: There is an association between dental fluorosis and dawa consumption in these children.

3. Is there an association between the presence of fluorosis among children in the Zing community and bambara consumption by these children?

H_0[1]Null hypothesis: There is no association between dental fluorosis in the children and their bambara consumption.

H_A[1]Alternative hypothesis: There is an association between dental fluorosis and bambara consumption in these children.

4. Is there an association between the presence of fluorosis among children in the Zing community and the use of clay pots in their households?

   H_0[1]Null hypothesis: There is no association between dental fluorosis in the children and the use of clay pots in their households.

   H_A[1]Alternative hypothesis: There is an association between dental fluorosis and the use of clay pots their households.

5. Is there an association between the presence of fluorosis among children in the Zing community and cropping on hilly sites?

   H_0[1]Null hypothesis: There is no association between dental fluorosis in the children and their cropping on hilly sites.

   H_A[1]Alternative hypothesis: There is an association between dental fluorosis and cropping on hilly sites.

6. Is there an association between the presence of fluorosis among children in the Zing community and the use of fertilizers for farming?

   H_0[1]Null hypothesis: There is no association between dental fluorosis in children and the use of fertilizers for farming.

   H_A[1]Alternative hypothesis: There is an association between dental fluorosis and the use of fertilizers for farming.

7. Is the severity of dental fluorosis in children in the Zing community associated with the level of fluoride exposure (dose) their water, foods and soil?

   $H_0{}^1$Null hypothesis: The fluoride in the water, soil and foods in this community is at the recommended level.

   $H_A{}^1$Alternative hypothesis: The fluoride in the water, soil and food in this community is significantly elevated over safe levels.

8. Are the children's dental caries or their families SES socioeconomic status potential confounders in the study outcome?

   $H_0{}^1$Null hypothesis: The children's dental caries or their families SES are confounders to the study outcome.

   $H_A{}^1$Alternative hypothesis: The children's dental caries and their families' SES status are not confounders to the study outcome.

Theoretical Foundation of the Study.

In this study, an ecological conceptual model, comprising multilevel influences on children's oral health, was used as a foundation (see Fisher-Owens et al., 2007). This model has 22 domains of influences. They were used to identify all related variables and to provide a framework for the analysis as it related to community, parental, and childhood influences on the development of dental fluorosis. At least 17 of the domains were explored. At the child level, these domains included genetic and biologic endowment, healthy development, physical and demographic attributes, health behaviors and practices, and use of dental care and dental insurance. At the parental level, these domains included family composition, SES, family function, health behaviors and coping skills, social support, and food culture. At the community level, these domains included health care system characteristics, dental care system characteristics, social environment, physical environment, and community oral environment such as availability of programs that promote oral care in the community. This model incorporated the five key domains of determinants of health as identified in the population health literature: genetic and biological factors, the social environment, the physical environment, health behaviors, and dental and medical care.

Easily identifiable community-level influences that relate to fluorosis could be the type of social environment that exist in the community such as, whether there is a good water supply, whether there are good dental care services, and whether there are peculiar cultural norms observed in the community, such as eating particular foods. Some parental influences could include the food culture of the family and practices, such as storing water in clay pots or cooking with clay pots. A single-parent family household might be poorly affected by its SES status and health-seeking behaviors. For the child level influences, such interesting attributes as, does the child utilize dental care services or enrolled in dental care insurance?

Children's oral health problems, such as dental fluorosis, could be impacted by various factors that are related to all three levels of influences i.e., (the community, parental, and childhood). Thus, a model that correlates these influences is appropriate to this assessment. As previously stated, the multilevel conceptual model developed by Fisher-Owen et al. (2007) provides a framework that can be used to assess influences that lead to dental fluorosis in children. By looking at potential causes at multiple societal levels these influences can be identified and assessed.

The multilevel conceptual model depicted in Figure 1 below, was developed over 25 years ago based on the population and social epidemiology fields moving toward multilevel, holistic approaches to analyze the complex and interactive causes of children's health problems (Fisher-Owen et al., 2007).

Implications of the Model

The implications of this model for the research questions in this study are that it offers possible explanations on how to draw inferences between dental fluorosis in children and various cultural and environmental influences. By looking at the domains through which potential inferences between dental fluorosis and cultural and environmental practices can be tested, the hypothesis of this study can be evaluated.

By answering Research Questions 2 to 7, the association between various cultural and environmental influences in the community can be inferred. Thus the model provides possible ways of addressing the influences that are linked to the community and the parent's and children's environments: for example, exposure of the children to fluorine when farming on the hillside, the provision of good dental care services, and access to a good water supply in the community.

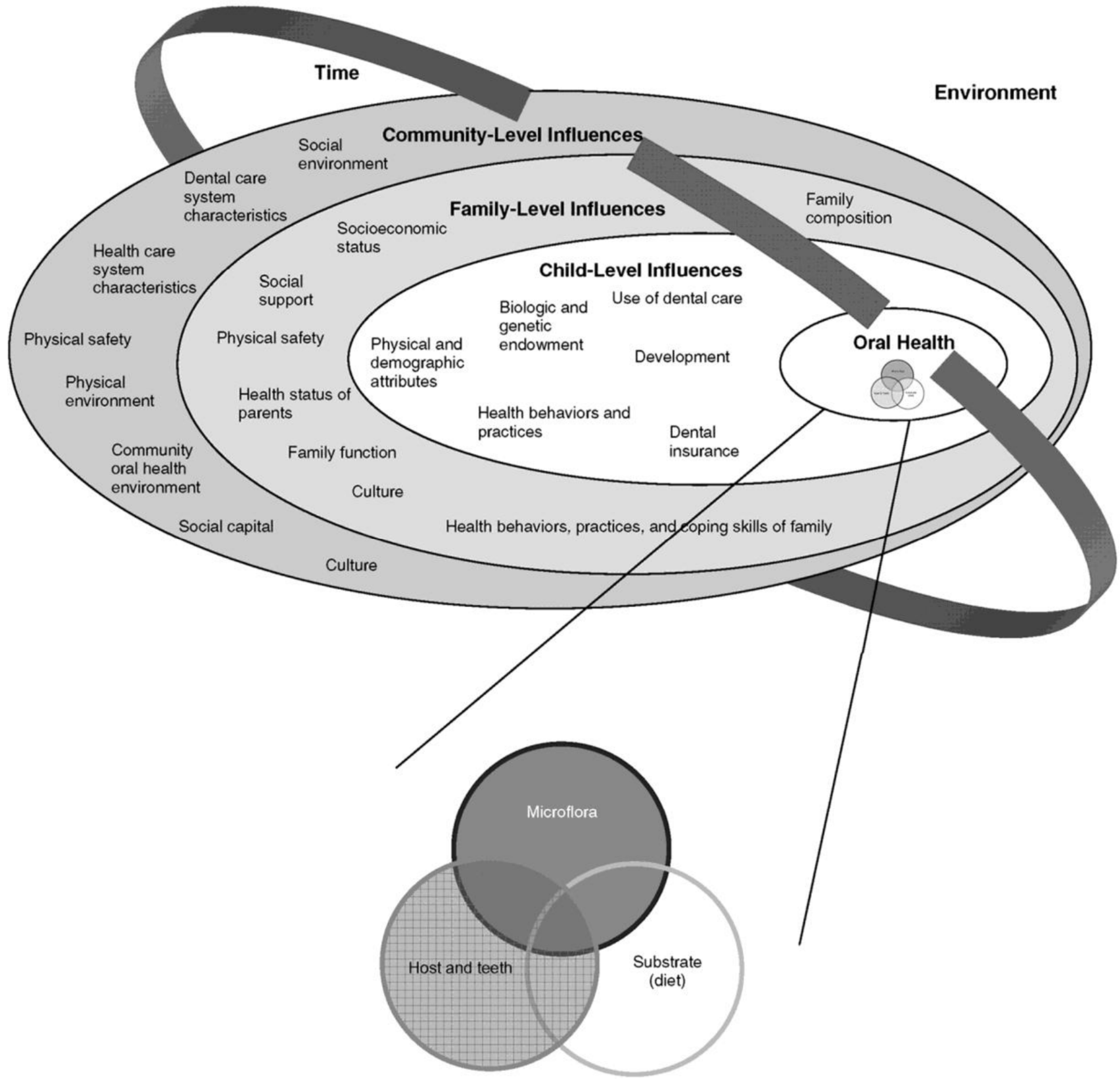

Figure 1. Fisher-Owen's et al., (2007) theoretical conceptual model.

Note: From "Influences on Children's Oral Health: A Conceptual Model" by Fisher-Owens , S. A., Gansky, S. A., Platt, L. J., Weintraub, J. A., Soobader, M. J., Bramlett, M. D. and Newacheck, P. W. 2007. *Journal of the American academy of Pediatrics 120,* (3), e510 – e520. Copyright 2007 by the American Academy of Pediatrics. Adapted with permission of the author.

Nature of the Study

This cross-sectional study used a quantitative research method to determine if there was an association between tooth fluorosis and various cultural and environmental practices among children in the Zing community in northeast Nigeria. When deciding on the best quantitative research design for this study, several points were taken into consideration. First, a quantitative approach was needed since the study involved finding an association between social constructs in the environment. Usually, quantitative designs are used to find causal associations (Creswell, 2009). As the research topic implies, this study sought to establish a causal association, and this could only be achieved by establishing a correlation among the variables in the study. Thus, the use of quantitative design was appropriate. Second, because the study involved assessing an association between variables that the children had been exposed before, it would be difficult to manipulate the independent variables. Thus an experimental design was not appropriate. Third, it was also not appropriate to use a quasi-experimental design since the treatment variables (water use, food culture and norms) were already in use in the community and it would be difficult to find comparison groups that were not already exposed to the variables to determine effects of the treatment on the development of dental fluorosis. The best research design for establishing an association between dental fluorosis and cultural and environmental determinants with prior exposure of children to the independent variables was a cross-sectional design. The dependent variable was dental fluorosis, while the independent variables were the fluoride content in the water, soil, and foods in use in the community.

The cross-sectional design utilized a number of survey instruments including survey questionnaires; procedures of WHO and the United Nation's Food and Agricultural Organization (FAO, 1985) for analyzing chemicals; and an ion-specific electrode potentiometer and/or spectrophotometer (a laboratory test) for measuring fluoride levels in the food, soil and water. The Dean (1942) classification of dental fluorosis and the Tooth Surface Index of Fluorosis (TSIF) scale were used as criteria for measuring the severity of fluorosis. The TSIF scale is a clinical test used by dentist to grade the appearance of fluorotic enamel changes characterizing the tooth surface (Horowitz, 1986).

The study participants were children of both sexes, aged 5 to15 years, residing in Zing and studying in one of the eight primary schools selected from among the 92 primary schools in the study area. The sample size for the study was 176 based on *t*-test table. The statistical power of 80%, the alpha level of 0.05 (95% CI), and the effect size was 0.30 for a small to medium effect (Cohen, 1998). However, an additional 25% was added to the sample size to make up for attrition, bringing the sample size to 220.

Study participants were selected through systematic random selection of every third pupil from each of the six grades in the selected schools. This process was continued until the sample size was achieved. The eligibility criteria were that the participants were born and reared in the community and fell within the age range of 5 to 15 years. Similarly, household information was obtained by enrolling all parents/guardian whose children were enrolled for participation in the study.

I determined the reliability and validity of the questionnaire instrument by administering the questionnaire to a similar population in a pre-test and then assessed how accurately the questions were answered. The other instruments (i.e., ion-specific electrode potentiometer and/or spectrophotometer and the Dean and TSIF scales) were tested by previous researchers in similar environments (Cao et al., 1997; Kahama et al., 1997; Fejerskov et al., 1990 ; Paul,Gimba, Kagbu, Ndukwe & Okibe, 2011).

Information generated for the study included community socio demographic data, responses to study questions from school children, and their parents in the survey questionnaires; environmental assessments of the fluoride content of water sources, soil, and food (carried out in collaboration with the chemistry laboratory at the Projects Development Institute); and clinical grading of the level of fluorosis (done in conjunction with a dentist at the federal medical center in the community).

The data analysis plan for the study involved collating, sorting, and coding the data points generated from the survey questionnaire. Using the SPSS, all the variables were input for each participant. The study variables were sex, age, place of residence (rural), duration of time residing in the community, source of water, occupation, farming site, hygiene practices, fluoride content of water, dental fluorosis and the cooking techniques.

The resulting data were then analyzed in the following ways: (a) demographic profiles were compiled for participants using frequency tables, noting age, gender, duration of residence; (b) graphs, pie charts, bar charts were created for graphical representation of the data to show the characteristics of the sample (Figures 2 to 13); (c) an independent-sample *t*-test was used to compare the mean ages of children with fluorosis and those without fluorosis (Appendix I). The inferences were then drawn from the variables of fluoride in the soil, water, and food; the inferences were then correlated with the severity of fluorosis in the children. Inferences were also drawn about the association of the variables of (a) dawa and bambara consumption, (b) the use of fertilizers, and (c) cropping on hillsides with fluorosis levels in the study sample. A Pearson correlation test was used to correlate the variables with the development of fluorosis in the study hypotheses. Finally, an ANOVA was performed to test for statistical significance.

Implications for Social Change

My study shall evoke social change through raising awareness about the problem of fluorosis and the possible ways to resolve it. Such possible ways include the need to (a) improve dental care services, (b) provide supportive social environment like flocculation of community water sources, and (c) change some community cultural practices that expose them to dental fluorosis. This awareness shall also lead to community mobilization of support for the attention of the state policy makers, the State Ministry of Health, and the Department of Water Resources, which are the agencies involved with the provision of basic services that can control the problem. Regarding this, the State Ministry of Health would be required to institute specific treatment for fluorosis in endemic areas, such as the use of flocculation or adsorption procedures in community water supplies.

Flocculation involves removing fluoride through a reaction with chemicals (usually hydrated aluminum salts) that coagulate the fluoride into flocs that settle at the bottom of a water container. Adsorption, however, involves filtering the water through a column packed with a strong absorbent, such as activated alumina, activated charcoal, or ion exchange resins (D'Alesandro, 2006). These two methods can be used for community or household water treatment plants, although they are costly. All these measures require resources to bring about change but they can be implemented if policy makers and legislators evidence a strong political desire to address the problem which will be raised through the awareness impacted by the study.

Operational Definitions

Some of the operational definitions in the study were as follows:

Dean index of fluorosis: Criteria developed by Dean in 1942 for classifying dental fluorosis (Horowitz, 1986);

Dental discoloration: Deviations in tooth color from the normal bluish white for primary teeth and greyish white or yellowish white for permanent teeth (Kumar et al., 2012);

Dental fluorosis: Tooth discoloration caused by fluorine that appears as barely noticeable whitish striations that may affect only a small portion of the enamel, or as confluent pitting of almost the entire enamel surface and unsightly dark brown to black staining (Horowitz, 1986);

Extrinsic discoloration: Discoloration on the outer surface of the teeth (Nathoo, 1997);

Fluorine: An element belonging to the halogen family of elements and is the 13^{th} most abundant element found in the earth's crust (Malde et al., 2011);

Hypo mineralization: Hypoplasia of the tooth enamel (Fejerskov et al., 1990);

Intrinsic discoloration: Stains deposited within the enamel of the dentin during the development of the tooth (Nathoo, 1997);

TSIF: Tooth Surface Index of Fluorosis used for classifying the severity of dental fluorosis (Horowitz, Driscoll, Mayers, Heifetz, & Kingman, 1984).

Assumptions of the Study.

This study was based on two assumptions: (a) the children were exposed to a high fluoride content in the water, food, and soil in the study area; and (b) this study will help raise the awareness of relevant authorities to the presence of the problem in order to bring about change.

Limitations of the Study.

This study was subject to four limitations: (a) a weakness of the cross-sectional study design used is the lack of adequate control over rival explanations; i.e., covariables could be confused for fluorosis, thereby leading to ambiguous inferences; (b) surveying children across the grades by the systematic random selection could, introduce selection bias if not controlled; (c) other limitations from the survey process could be nonresponse error, interviewer effect; and (d) the reliability of the measurement instruments i.e. the questionnaire and the spectrophotometric method used in the study could never be 100%.

Scope and Delimitations

This was approached by addressing the problem of external validity, through collecting data from as many primary sources as possible using the limiting criteria of children aged 5 to 15 years, born and raised in the study area thereby preventing the study outcome to be influenced by factors extraneous to the area. This involved attempting to reach all study participants to attain the sample size for the study. Secondly, to address the problem of internal validity; (a) the validity of the questionnaire as measurement instrument was tested through a pilot test in a similar population with a view of checking if participants responded correctly to the questions; and (b) the validity of the dentist grading of fluorosis was checked using the test re-test method and cronbach alpha calculated to know how consistently was the right diagnosis made. Thirdly, to address generalizability, the study adopted a systematic random selection of participants across the participating schools and class grades.

Summary

Dental discoloration from fluorosis is a global public health problem. In Nigeria for example, 11.4% of the population is impacted by this disorder. Dental fluorosis is caused by successive exposures to high fluoride concentrations during tooth development in utero and it is linked to the development of a variety of psychological and physiological problems, from dental aesthetics to a reduction in intelligence and skeletal changes.

The purpose of this quantitative, cross-sectional study was to examine the cultural and environmental determinants of dental fluorosis in children in a rural community in Nigeria. Information was sparse. The study participants were children aged 5 to15 years, residing in Zing and studying in one of the eight primary schools selected from among the 92 primary schools in the study area. The sample size for the study was 176 based on *t*-test table and the study participants were selected through systematic random selection from each of the six grades in the selected schools. Household information was obtained by enrolling all parents/guardian whose children were enrolled for participation in the study. A pre-test of the questionnaire was conducted to assess how accurately the questions were answered.

A multilevel theoretical model was used to develop possible fluoride exposure pathways, such as good social services and dental care, as well as factors in the environment. The study was guided by two main research questions: What is the prevalence of fluorosis among Nigerian school-aged children? What is the severity of this fluorosis, and is it associated with the fluoride content of the soil, the water or the food?

The data analysis was done using SPSS for collating, and coding the data points generated from the survey questionnaire. The resulting data were analyzed for demographic profiles using frequency tables and graphs, while Chi-square and regression analysis tests were used to test for possible associations listed in the research questions.

My study's impact on social change include raising awareness to the problem and the possible ways to resolve it, such as through, improved dental care services and a supportive social environment like flocculation of community water sources.

The main assumptions of the study were that children were exposed to a high fluoride content in the water, food, and soil in the study area and that this study will help raise the awareness of relevant authorities to the presence of the problem in order to bring about change. The study was subject to the limitations of the weakness of cross-sectional study design in the lack of adequate control over rival explanations, introduction of selection bias through the survey process, as well as nonresponse error, and the problem of the reliability of the measurement instruments used in the study.

Chapter 2: Literature Review

Introduction

The purpose of this quantitative, cross-sectional study was to examine the cultural and environmental determinants of dental fluorosis among children in the Zing local government area, a local settlement in northern Nigeria. The purpose of this chapter was to review the literature on dental discoloration caused by fluorosis. This review focuses on how dental fluorosis is acquired both through (a) cultural practices, such as choice of food, and (b) environmental influences, such as altitude, climate, and exposure to chemical agents in the environment. Fluorosis affects both children's oral health and quality of life because even the mildest form of tooth discoloration is considered cosmetically unacceptable and is a cause of psychological concern for those affected (Kumar et al., 2012).

The Aim of Study

The aim of the study is to explore the relationships between local cultural practices and environmental characteristics and the presence of fluorosis among children aged 5 to15 years in this region of Nigeria.

Study Objectives

The objectives of the study are the following: (a) assess the prevalence and severity of dental fluorosis among children in the study area; (b) assess the presence of fluorine in soil, food, and water in the study area; (c) identify local practices (diet, behaviors, household use of clay material for food and water storage, etc.) and their association with fluorosis in the study population; and (d) identify local environmental practices and their association with fluorosis in the study population.

Literature Search Strategy

To identify prospective, peer-reviewed articles and books, the following databases- PubMed, academic research database of Walden University, and the EBSCO host engine,- were searched for the past 5 to 10 years using the keywords: *dental fluorosis, children, culture, environment*. I used Boolean operators and filters to optimize results. Abstracts were used to judge the article's relevancy to the research questions. On using the PubMed search engine, the terms *dental fluorosis* and *children* produced 1,290 articles. When I applied filters to limit the search to full text articles published in the past 5 years, this resulted in 190 articles. However, when the terms *dental fluorosis, children*, and *culture* were used, PubMed produced only five articles in the last 5 years. This was also the same for the past 10 years. On the other hand, when the terms *dental fluorosis, children,* and *environment* were applied, PubMed produced 30 full texts articles for the past 10 years. Literature searches are generally focused on peer-reviewed articles. However, by using the academic research database of Walden University and the EBSCO host engine with the search terms, 'dental fluorosis' ' children,' and 'culture' I found 34,608 articles while the terms 'dental fluorosis', ' children,' and 'environment' yielded 35, 922 articles. I did not strictly applied the limiting terms for this search; when I did limit the terms, no articles were found for dental fluorosis children, culture, and environment. Therefore, most of the articles used for this study were those related to dental fluorosis in children, culture, and environment.

I was able to access some relevant articles in the field of dentistry that dealt with criteria for classifying dental fluorosis as well those that discussed the mechanism of dental fluorosis using the special delivery system available through the

Walden University library. Due to the relevance of these articles, they were also used in the study although they were published 20 to 30 years ago.

This review of the literature starts with a discussion of dental discoloration caused by fluorosis in children as an emerging public health problem in the society at large and specifically in developing countries due to the presence of poor oral hygiene.

Review of the Literature

Fluorosis Worldwide

Fluorosis has been found to be endemic in a minimum of 25 countries across the world (UNICEF, 2014), including Mexico, and Argentina, in the North and South American continents; Ethiopian, Uganda, Kenya and Tanzanian Rift Valley in East Africa; and Algeria, Morocco, Egypt, and Libya in North Africa. Fluorosis is present in parts of central and western China, Bangladesh, Thailand, Pakistan, India, the SriLankan axis, Japan, Australia, and New Zealand (UNICEF, 2014).

Common Risk Factors for Dental Fluorosis

Alvarez et al. (2009) have identified common risk factors for dental fluorosis, including successive exposures to high concentrations of fluoride during tooth development. Patel et al. (2013) have noted that the fluoride concentration of naturally fluoridated water varies, depending on the geographic location. For example, in some areas of Africa, the concentration is as high as 10 ppm while artificially fluoridated water is usually 1 ppm (Patel et al., 2013). This is in agreement with the observations by Allen (2003), who, in reporting assessment of oral quality of life by Slade, Spencer, Locker, Hunt, Strauss, and Beck, (1996) noted that there was an observable difference in tooth loss in six populations aged 65+ years across six communities with distinct cultural and economic differences. These communities were an urban and a rural community in South Australia, a metropolitan and non-metropolitan community in Ontario, Canada, and an Afro-American and Caucasian communities in North Carolina U.S.A. This may suggest cultural and economic influences on oral health outcomes.

Geographical Distribution of Fluorine

Fluorine is a member of the halogen family and the 13th most abundant element found in the earth's crust (Malde et al., 2011). The geological fluoride belt extends from Turkey up to China, and from Japan through Iraq, Iran, and Afghanistan. There are about 85 million tons of fluoride deposits on the earth's crust, 12 million tons of which is in India (Saravanan et al., 2008). Analyses of the geochemical composition of rocks and minerals and the geographical distribution in Nigeria suggest that there are high fluoride concentrations in the rocks and soil around the Gombe and Kaltungo areas of the Upper Benue sedimentary basin (Lar & Tejan, 2008). Interactions between water and the soil and rock formations around this region leads to a dissolution of the constituent fluoride compounds, leading to the presence of soluble fluoride in many water sources in this region. The level of concentration of these elements in water depends on the prevalence of fluorine-bearing minerals in the area where they are leached into the bodies of water (Lar & Tejan, 2008). The area of focus for this study (Zing in the Taraba state) lies close to the Gombe and Kaltungo areas of the upper Benue sedimentary basin. However, fascinating rock formations like the Bitako rock also exist in the Zing area complementing the topography of this region. Zing is found to be rich in such minerals like iron ore (Ambinkanme et al., 2014).

Case Definition and Clinical Features of Dental Fluorosis

The clinical features of dental fluorosis have been described by many researchers over the years. Horowitz (1986), citing Kuhn (1888), noted that fluorosis was first observed in areas of Mexico as opaque, discolored, and disfigured teeth. Similarly it was later termed Colorado brown stain in 1916 among persons living in particular communities (Horowitz, 1986). The term *mottled enamel* was later used to describe the condition, in order to not restrict the meaning to a particular region. However, Dean (1934, 1942) developed a classification system for assessing the presence and severity of dental fluorosis, which he later modified and is still used today. This classification system as describe in table 1 below, shows that dental fluorosis, which presents as hypoplasia or hypomineralization of tooth enamel, ranges in intensity from barely whitish striations to confluent pitting and staining.

Table 1

Dean's Classification System for Dental Fluorosis.

Classification	Grading	Criteria
Normal	0	The enamel represents the usual translucent semivitriform type of structure. The surface is smooth, glossy, and usually a pale, creamy white color.
Questionable	0.5	The enamel discloses slight aberrations from the translucency of normal enamel, ranging from a few white flecks to occasional white spots. This classification is used in those instances where a definite diagnosis of the mildest form of fluorosis is not warranted and a classification of "normal" is not justified.
Very mild	1.0	Small, opaque, paper-white areas are scattered irregularly over the tooth, but do not involve as much as approximately 25% of the tooth surface. Frequently included in this classification are teeth showing no more than about 1 to 2 mm of white

		opacity at the tip of the summit of the cusps of the bicuspids or second molars.
Mild	2.0	The white opaque areas in the enamel of the teeth are more extensive but do not involve as much as 50% of the tooth.
Moderate	3.0	All enamel surfaces of the teeth are affected and surfaces subject to attrition show wear. Brown stain is frequently a disfiguring feature.
Severe	4.0	All enamel surfaces and hypoplasia is so marked that the general form of the tooth may be affected. The major diagnostic sign of this classification is discrete or confluent pitting. Brown stains are widespread and teeth often present a corroded-like appearance.

Note: From Indexes for Measuring Dental Fluorosis by H.S. Horowitz, 1986. *Journal of Public health Dentistry, 46,* 179 – 183.

In every stage of Dean's classification system, all of the clinical features of dental fluorosis range from *barely noticeable whitish striations* that may affect only a small portion of the enamel to *confluent pitting* of almost the entire enamel surface and unsightly dark brown to black staining. These teeth that are severely affected may be *cosmetically compromised* due to their corroded appearance and may be subject to fractures (Horowitz, 1986).

Although Dean's classification was considered limited, necessitating further suggested improvements in this classification by other researchers (i.e., Moller, 1965; Thystrup & Fejerskov, 1978), the index has remained very useful in dental fluorosis studies. To avoid some of the short-comings associated with Dean's classification system, the TSIF was developed. This classification (reproduced in table 2 below) was successfully used in surveys to assess the prevalence of dental caries and dental fluorosis in Illinois communities with optimal and above optimal concentrations of naturally occurring fluoride in their drinking water (Horowitz, 1986).

Table 2
Descriptive Criteria and Scoring System for the TSIF

Numeric Score	Descriptive Criteria
0	Enamel shows no evidence of fluorosis.
1	Enamel shows definite evidence of fluorosis, namely areas with parchments-white color that total less than one-third of the visible enamel surface. This category includes fluorosis confined only to incisal edges of anterior teeth and cusp tips of posterior teeth (“snow capping”).
2	Parchment-white fluorosis totals at least one-third of the visible surface, but less than two-thirds
3	Parchment-white fluorosis totals at least two-thirds of the visible surface.
4	Enamel shows staining in conjunction with any of the preceding levels of fluorosis. Staining is defined as an area of definite discoloration that may range from light to very dark brown.
5	Both discrete pitting and staining of the intact enamel exist
6	Confluent pitting of the enamel surface exists. Large areas of enamel may be missing, and the anatomy of the tooth may be altered. Dark-brown stains are usually present.

Note: From Indexes for Measuring Dental Fluorosis by H.S. Horowitz, 1986. *Journal of Public health Dentistry, 46,* 179 – 183.

The sensitivity of the TSIF index can discriminate between the prevalence and severity of fluorosis in four groups of communities with different concentrations of fluoride in their drinking water (Horowitz, 1986). Although a previous study by Thylstrup and Fejerskov (1978) proposed a new classification system that included 10 scores for dental fluorosis based on clinical appearance and histological changes in permanent teeth (i.e., the TF index) it is suggested by other researchers (Horowitz et al., 1984), that this does not translate to greater accuracy or sensitivity in defining cases as well as being interpreted precisely and easily by others. Moreover, Thystrup and Fejerskov (1978) used an unnatural technique of compressed air to dry teeth thoroughly before examination which meant that their examinations were not carried out in a natural state. Thus, the TSIF method, which examines teeth under normal conditions - the teeth are kept moist by saliva which approximates the normal social conditions that people operate in - is preferable. The TSIF score is given to only fully erupted tooth surfaces, and air is not used to dry the teeth.

Prevalence of Dental Fluorosis

The prevalence of dental fluorosis in children varies across the world depending on the geochemical composition of the region. For instance, one study on the prevalence and severity of dental fluorosis in Nigeria put the rate at 11.4% among children aged 12 to 14 years in the urban settlement of Ibadan. The study did not record any significant difference between age or gender and the occurrence of fluorosis (Ajayi, Arigbede, Dosunmu, & Ufomata, 2012). Similarly, among primary school children in rural India, the prevalence rate was found to be 31.4% (Saravanan et al., 2008). This study also found no significant difference between genders. However, the prevalence rate of dental fluorosis among children in China was much higher, with a rate between 52 and 84% in the Mongol, Kazak, and Yugu areas in the Gansu Province of China (Cao et al., 1997). This rate appears even higher in some areas of the world with intense volcanic activity. For instance, the prevalence rate in children aged 2 to 14 years living around Lake Elementaita in Kenya was estimated to be up to 95. 9%(Kahama et al., 1997). This area is located near the Rift Valley, which is continuously prone to intense volcanic activity. Similarly, in populations living around Ambrym Island in the Vanuatu archipelago, an island prone to volcanic eruption and degassing, the prevalence of dental fluorosis is found to be as high as 61% to 91% (Allibone et al., 2012). The areas within a 50 km radius of the volcanic zone were found with fluorosis rates of 96% (West Ambrym), 71% (North Ambrym), 61% (Southeast Ambrym), and 85% (Malakula Island) while Tongoa Island, a nearby area rarely affected by volcanic emissions had a prevalence rate of 36% (Allibone et al., 2012).

Available Tools for Estimating Fluoride

Various tools had been developed over the years for estimating the fluoride content of various substances, including water, food substances, soil, and urine. Some of these tools include the WHO/FAO guidelines for measuring chemical contaminants in diet. This method, which is described in the methods section of this paper, involves measuring the quantity of fluoride in samples of water, food, and soil through acid treatment and fluoride-selective electrodes (Cao et al., 1996), such as the spectrophotometric method or the ion-specific electrode potentiometer.

Theoretical Foundation

Theory and Its Origin

As a theoretical foundation, this study utilized the model for assessing the influences on children's oral health proposed by Fisher-Owens et al. (2007). This conceptual model was derived from the fields of population health and social epidemiology which focus on multilevel approaches to analyzing children's health problems. The model looks at five determinants of population health: genetics and biology, social environment, physical environment, health- influencing behaviors, and dental and medical care. The model also identifies the interplay of complex causal factors from the social environment as well recognizing that children's oral health diseases evolve with time. The model focuses on understanding children's oral health determinants at the individual level (Edelstein, 2008).

Theoretical Assumptions

The major theoretical propositions of the model developed by Fisher-Owen et al. (2007) include the following: (a) there are multilevel determinants of childhood oral health; (b) these factors are expressed at the individual, family, and community levels and are interrelated; and (c) children's oral health is accounted for with changes over time. The model recognizes that health and its determinants form a dynamic, evolving system that includes time.

Several significant influences are highlighted in this multilevel model. These are as follows: Child-level influences; (a) biological and genetic endowments can provide an inherited predisposition to responses affecting health status; (b) physical and demographic attributes, such as race and ethnicity, appear to influence children's oral health both directly and indirectly. Some of these influences stem from SES and demographic confounding; (c) health behaviors and practices are related to diet and nutrition, good oral health habits, and exercise. Thus, insufficient tooth brushing and frequent consumption of carbohydrates or sweet liquids are risk factors for poor oral health in children; and (d) the availability and use of dental care services promote good oral health.

Family – level influences include: (a) family composition, such as a single parent or reconstituted household, can increase the risk for children's poor oral health; (b) family functions, such as an interest in a child's activities like dietary rule, can impact on children's oral health; (c) SES like including parents' education levels and income, can impact their children's oral health status; i.e, higher income promotes improved living conditions and the consumption of healthy food; (d) the health behaviors, practices, and coping skills of family, like the consumption of folic acid during pregnancy, helps to prevent cleft lip and palate in children; (e) social support, like support from families, friends, and communities, is associated with better oral health; and (f) cultural practices have many influences on childhood oral health, such as diet, health care use, and family interactions.

Community level influences include the following: (a) social environments such as a good neighborhood provide a supportive environment that potentiates good health. It has been noted that dental morbidity is linked with a high neighborhood poverty rate (Fisher- Owens et al., 2007); (b) lack of physical safety such as trauma, from unsafe playgrounds, and violence can cause dental injuries; (c) physical environments like the fluoridation of public water supplies, can reduce dental disease; (d) the community oral health environment, such as oral health promotion campaigns, can improve the oral health; (e) the availability of dental care practitioners in communities can improve oral health; and (f) A community's cultural norms and practices can influence children's oral health through diet, belief systems, and behaviors. Culture is known to affect tooth brushing habits and methods, diets, and methods of food preparation and types of foods eaten (Biazevic et al., 2004).

Prior Empirical Application of Theory

The empirical application of this conceptual model is based on identifying key influences on children's oral health, including genetic and biological factors, social and physical environments, support systems, health behaviors, and dental and medical care.

All this represents strengths that can be utilized for the application of the model. Isong, Luff, Perrin, Winickoff, and Wai Ng (2012) applied this model to some degree to study the parental perspectives of the prevention and management of early childhood caries. They identified factors that influence caries prevention, including, social milieu, family factors, parental factors, provider/system factors, parent/provider interaction, and child factors. All these factors could be assessed according to their influence on the children's oral health model.

An article by Edelstein (2008) on environmental factors that could impact the implementation of a dental home for all young children utilized this model's breakdown of the different influences on children's oral health. Edelstein (2008) found that preventing childhood caries requires focusing on multilevel influences, thus going beyond the child's mouth to his or her environment. In this regard, social environmental factors such as poverty/low income-families and racial and ethnic minority status were found to be associated with childhood oral health problems. Furthermore, these factors were found to account for dental disparities in the United States (Edelstein, 2008).

Rationale for the Choice of Theory

Children's oral health problems including, dental fluorosis, are influenced by various factors that are related to their communities, parents and the children themselves. Thus, a model that can correlate these influences is appropriate for this assessment. This model developed by Fisher-Owen et al. (2007) presents a framework that can be used to examine those influences that lead to developing dental fluorosis in children.

How the Selected Theory Relates to the Present Study

This theory, with identified 22 oral health domains (Fischer-Owen et al., 2007), across the three levels of child, family, and community provides a framework for the current study particularly in relation to exploring and furthering the current understanding of factors that contribute to positive oral health among children. The variables outlined in Research Questions 2 to7 are some factors that need to be explored to understand how influences at these levels contribute to positive childhood oral health. For example, answering Research Question (Is there an association between the presence of fluorosis in children and dawa consumption?) will help us understand if the food-related cultural norms of the community- a community level influence can contribute to the development of childhood oral health. Similarly, Research Question 3 (linking bambara consumption to childhood oral health) is also a community level influence that is associated with the local food culture. Question 5 (that focuses on cropping on hilly sites) relates to the environment of the community, and Question 7 (which compares the severity of fluorosis to the fluoride content of water, soil, and foods) will help us understand the community-level influences as it presupposes a lack of good water supply and safe food in the community. Therefore in this study, Research Questions 2, 3, 5 and 7 will highlight the community-level influences associated with childhood oral health. The community-level influences emphasized in the multilevel model include a social environment that supports good health, physical safety, a positive physical environment (e.g. a public water supply, community oral health, and a good dental care system), and culture. Therefore, the research questions in this study will provide information about four of the community-level influences social environment, physical environment, culture, and physical safety.

Similarly, concerning parental perspectives, Research Questions 4 and 6 will provide information about family-level influences related to food culture, SES, family functions, etc as they focus on the type of foods consumed and whether the SES status necessitates the use of clay pots for storing water or for cooking. Furthermore, Child-level influences can be examined in this study by answering Research Questions 1 to 3 through finding an association among physical and demographic attributes, and health behavior and practices related to diet and nutrition. Overall, this approach will help me analyze many of the influences affecting childhood oral health at all the three levels of influence.

Review of Literature Related to Key Variables

Most of the studies reviewed that focused on environmental and cultural practices that promote dental fluorosis in children were cross-sectional and used quantitative methodology (Cao et al., 1996; Cao et al., 1997; Kahama et al., 1997; Lu, Li, & Zhang, 2011; Malde et al., 2011). Although the study populations for all of the studies were comprised of children, they were conducted in volcano-prone high altitude environments. None of these studies were conducted in Nigeria which is the focus of this study. The one study that drew its population from Nigeria only looked at the prevalence of dental fluorosis and not the cultural and environmental practices associated with dental fluorosis (Ajayi et al., 2012). All these factors make generalization of findings inappropriate.

Exposure Pathway of Fluorine: Environment

As previously stated, the study area (Zing in Taraba State) lies close to the Gombe and Kaltungo areas of the Upper Benue sedimentary basin. Fascinating rock formations like the Bitako rock exist in Zing, complementing the topography of this region. In addition the study area Zing is found to be rich in such minerals like iron ore (Ambinkanme et al., 2014). However, there is no information on fluoride levels previously identified in this region. The study area is hilly and mountainous, and the weather is usually hot except during the short period of rain lasting about 4 months (Ambinkanme et al., 2014). Although no other studies on fluorosis were conducted in this area, the high altitude may favor the development of fluorosis because, as noted by Fejerskov and colleagues (1990), temperature affects the prevalence and severity of dental fluorosis through variations in daily consumption of water.

Any use of fluoride, whether systemic or topical, such as for caries prevention and treatment in children, can result in ingestion and absorption of it into the blood stream. The mineralization of teeth under formation may be affected, thereby producing dental fluorosis (Fejerskov et al., 1990). The exposure pathway of fluorosis may be due to accidental exposure or from endemic sources. The various exposure pathways for fluoride to be absorbed into the body include water, food, soil, air, topical application, climate, etc. As noted earlier, Patel et al. (2013) indicated that the fluoride content of naturally fluoridated waters may be as high as 10 ppm in some parts of Africa. This is especially so in areas where the underground water is contaminated by the emission of fluorine from rocks. For instance, the fluoride content in the various drinking water sources around Lake Elementaita in Kenya, where the prevalence of dental fluorosis is about 95.8%, varies from 20 to 20.9$\mu g/ml^{-1}$ (Kahama et al., 1997). In areas around Vanuatu, drinking water sources such as rain water samples had an average of 4.2 ppm(0.7 - 9.0 ppm) and ground water sources had 1.8 to 2.8 ppm with an average of 2.2 ppm (Allibone et al., 2012). All these averages are more than the 1.0 ppm, the recommended concentration of fluoride in drinking water in such climates (Allibone et al., 2012). When this concentration is compared to the fluoride content of municipal water supply/bottled water used in a city such as Indianapolis, Indiana, where the concentration is 0.006 to 0.740 μg/ml (Steinmetz et al, 2011), the disparity becomes obvious. While the high concentration of fluoride in the former cases can predispose the population to developing dental fluorosis, the latter concentration helps to prevent dental caries.

Another important pathway through which fluoride is ingested into the body is the food chain. Some studies (Kahama et al., 1997; Cao et al., 1996) have measured the fluoride content of soil in which vegetables are grown as well as the various food types in such areas with high fluoride contents. One study in East Africa (Kahama et al., 1997) showed that the fluoride content of the soil where vegetables were grown was as high as 1,000 ppm and the level of fluoride in the vegetables was as high as 7.9 to 59.3μg/l. The fluoride content of milk from cows grazing in the same area was also high (0.05 to 0.22μg/l) when compared to milk from cows grazing in other areas (Kahama et al., 1997). A study in China also measured the fluoride content of foods eaten by Tibetans and found that the content of *zenba* was 5.12 ± 2.80mg/kg brick tea with milk was 2.59 ± 1.73 mg/l (Cao et al., 1996). All these values contribute to a daily fluoride intake of more than 5.49 mg per child and 10.43 mg per adult in this area, thereby accounting for the high rate of fluorosis in this population.

Another pathway for fluoride ingestion is a contaminated environment and food chain through the agricultural application of pesticides and fertilizers, as well as industrial activities that lead to the contamination of water sources (ground water, surface waters) and agro-ecosystems by fluoride (Pandey & Pandey, 2011). Pandey and Pandey (2011) indicated that industrial activities, particularly those of phosphate fertilizer factories, aluminum factories and glass fiber factories produce air borne fluoride in their vicinities and that the inhalation of such fluoride can significantly enhance human exposure to fluoride (Pandey & Pandey, 2011). These authors also demonstrated that air borne fluoride from such industrial activities was a major factor for the higher prevalence of fluorosis in the rural areas where these activities were taking place. This is in agreement with the study by Allibone et al. (2012), who also noted that hydrogen fluoride (HF) gas emitted as a constituent of volcanic gases contributed to damaging vegetation and impairing photosynthesis, growth and reproduction. The study noted that HF is very soluble in water and is thus readily dissolved in rainwater, becoming mobile and bioavailable. This therefore increases the fluoride content of water and also contaminates the food chain. It was noted that fluoride can also be transferred to the earth's surface through dry deposition; i.e., as a gas or aerosol (Allibone et al., 2012).

High altitude and weather have also been identified as pathways through which fluoride ingestion is increased. For example, previous studies had reported that temperature affects the prevalence and severity of dental fluorosis through variations in the daily consumption of water. In this regard, Fejerskov et al. (1990), citing Galagan and Vermillion (1957), provided an equation that relates the dose of fluoride ingested as the sum of the concentration of fluoride in water multiplied by water uptake. This is represented as:

Dose (mgf/kg) = water f concentration (mgf/l) x water intake (l/kg body weight).

This can be calculated to be equivalent to:

Dose (mg/l) = water f concentration (mg/l) x (-0.0024775 + 0.00040423 x mean max temp ^{o}F).

Using this formula, the daily dose of fluoride intake from drinking water could be calculated once the mean maximum air temperature is known. It is suggested that a high altitude exacerbates dental fluorosis especially among children (Cao et al., 1997). Cao et al. (1997), citing other researchers (Whitford et al., 1983; Whitford & Angmar-Mansson, 1995; Zhang et al.,1995), noted that when there is a of lack of oxygen, rats take up more fluoride and that the growth of enamel is unfavorably affected. They also found that reduced air pressure can change the metabolism balance of fluoride and calcium all of which can exacerbate dental fluorosis in children living at high altitudes.

Dental fluorosis in children is also associated with the topical use of fluorine, such as in toothpaste. A study conducted in India (Tiwari, Kaur, & Sodhi, 2010) found an association between a type of fluoridated toothpaste and the development of dental fluorosis. The study, which drew a total of 432 participants from middle schools, noted a 29.3% prevalence of dental fluorosis and a statistically significant association (p<0.033) with the toothpaste.

Exposure Pathway of Fluorine: **Cultural Practices**

The various pathways that could lead to the development of dental fluorosis in children are explained above. However, there exist certain cultural practices that could predispose a population to the development of dental fluorosis. In the study area, such cultural practices are related to the food culture, such as the consumption of dawa, bambara, and yam, which are commonly cultivated here. Other cultural practices, such as cooking with clay pots or storing water with clay pots, abound in the study area.

Although information on the fluoride level of these food-related cultural practices has remained sparse in the study area and Nigeria in general, many attempts have been made by researchers to establish the cultural basis of fluorosis in some populations of the world. However, these attempts left some gaps in the existing literature. Very interesting and enlightening information emerged from studies carried out among the Tibetan population in China and residents of south-western China (Cao et al., 1996; Cao et al., 1997; Lu et al., 2011), Ethiopia (Malde et al., 2011), and Kenya (Kahama et al., 1997). Most of the findings from these studies identified food culture as a major cultural pathway through which people develop fluorosis. As stated previously, Tea is a traditional beverage for Chinese people and its safety is generally not questioned. However, brick tea is made from low quality older leaves and contains much higher levels of fluoride than standard teas, such as black tea or green tea, which are made from tender leaves and buds. In this study, Cao et al. (1996) compared the food habits of the Tibetans living in the region and the Han residents and they identified brick tea and zanba (a type of food made from roasted *qingke* barley flour) as the main food items that were by more Tibetans than Han*s.* These two food items had high fluoride concentrations and the morbidity rate of dental fluorosis in Tibetan children was higher than that in Han children at 50.2% and 12.8% respectively (Cao et al., 1996). It is important to note that the Han population also drank tea, but they generally drank green tea. These cultural food habits accounted for the difference in the prevalence of dental fluorosis. In another study by Cao et al. (1997), a further correlation was drawn between the tradition of brick tea consumption and the prevalence of dental fluorosis in children. This study focused on three population groups (the Mongol, Kazak, and Yugu) in the Gansu province of China.

The results showed that brick tea had a high fluoride content and that after brewing, there was still a high concentration of fluoride in the tea water. The prevalence of dental fluorosis was significantly correlated with the concentration of fluoride in the milk tea and not with fluoride levels in any other dietary component analyzed, including the drinking water (Cao et al., 1996). The study also noted that this prevalence and severity of dental fluorosis was highest among the Kazak population, who had the greatest intake of fluoride from tea. These findings are very important and the studies were well conducted. One of the strengths of these studies was the large sample sizes, (the first study had a sample size of 536 children aged 8 to 15 years and the second study had a sample size of 590 children, aged 8 to 15 years), which also improved the power of the study.

However, these findings may not be generalizable to other areas because, the areas in the two studies were located at very high altitudes. The first study was conducted at an altitude of 2,900 to 5,800 m above sea level, with an annual average temperature of 3.9^{o}C to 7.8 ^{o}C (Cao et al., 1996), while the second study was conducted at an altitude of 1,400 to 5,770 m above sea level (Cao et al., 1997).

Another cultural practice found to be associated with dental fluorosis is the use of coal for roasting corn and chili. The study by Luo et al. (2011) indicated that there is a correlation between a prevalence of dental fluorosis in children and eating a diet high in roasted corn before the age of 6 years. They highlighted that the association was almost 100%, as the prevalence of dental fluorosis in children who ate roasted corn was 95% while the prevalence of dental fluorosis in children who didn't eat roasted corn or rice was less than 5%. They (Luo et al., 2011) also noted that the average fluoride concentration was as high as 20.26 mg/kg about 16 times higher than in non-roasted corn. They noted that the main source of pollution of the roasted corn and chili was the briquette coal and binder clay. This study, which was conducted in southwestern China, had a sample size of 405 children. However, although the findings are interesting, they cannot be generalized, because the briquette coal and binder clay which the researchers found to be the source of fluoride are associated with only this region. This coal may have been harvested from soil with a high fluoride content, and this cultural practice may be associated only with this region.

In a case of substance flow analysis of fluoride exposure through food and beverages in young children living around the Ethiopian Rift Valley, Malde et al. (2011) noted that high amounts of fluoride were retained in food prepared with high fluoride water. They also identified sources of fluoride to include the main food staples in this region including Injera made from teff. Of the common food substances in the Ethiopian kitchens, teff and tea leaves were found to contribute fluoride to the diet regardless of the fluoride concentration in the water source. Indeed injera and tea had the greatest contributions to fluoride intake, and ijera prepared with high fluoride water contributed significantly to the total fluoride intake (Malde et al., 2011). Moreover, the water around the Valley had a fluoride content of up to 41%. Like the Kenyan Rift Valley, the Ethiopian Rift Valley is located in a volcano-prone region and the food substances grown around this valley are exposed to high fluoride levels. The study by Kahama et al. (1997) also highlighted similar findings; i.e., high fluoride levels in the soil, vegetables, and milk which accounted for the fluoride intake in these populations. However, as both of these studies were conducted in the Eastern African region at high altitudes, the findings cannot be generalized to other cultures like Nigeria due to the different climates, food culture, and altitudes.

The study that investigated the prevalence and severity of dental fluorosis in Nigeria was carried out in an urban setting, namely Ibadan in Western Nigeria (Ajayi et al., 2012). This study did not look at cultural and environmental practices that could predispose a population to developing dental fluorosis and the location was different from the location of the current study. These regions have quite different and distinct cultural practices including their food cultures. They also have different climate conditions that translate to the food types available. While the climate in western Nigeria is mainly cold and the environment is wet because of more frequent rainfall, the northeast region of Nigeria where this study was situated is usually hot, dry, and windy with very little or minimal rainfall (Total Nigeria, 2014). Moreover, the lower altitude in Western Nigeria and its proximity to the Atlantic Ocean means that more tubers are grown, compared to north-east Nigeria, where more grains are grown because of the sparse rains (Oyo State, 2012). The area for the present study was also located at a higher altitude than the study conducted in western Nigeria.

There are also differences in the participants of these two studies. The study in western Nigeria focused on children aged 12 to14 years. The researchers randomly selected secondary schools, where the questionnaires were sent with the students for their parents to fill out. This method can introduce a nonresponse error. Furthermore, the study utilized the TF index for the classification of dental fluorosis but this method, which uses polarized light and an ordinary microscope to characterize scores, does not necessarily translate to more sensitivity. On the other hand, the sensitivity of the TSIF index, which the present study used, can discriminate between the prevalence and severity of fluorosis in four different community groups with different concentrations of fluoride in their drinking water (Horowitz, 1986), making the TSIF index more sensitive than the TF index.

These differences in methods and approach makes it difficult to generalize the findings of the study conducted in western Nigeria to the present study in north-east Nigeria. All the factors and the observations of the other studies conducted in China prevent us from generalizing those findings. Therefore the present study seeks to fill this gap in knowledge on the cultural and environmental factors that contribute to the development of dental fluorosis in this region.

Summary and Conclusion

As the literature showed, various environmental and cultural factors predispose children to the development of dental fluorosis. Among many of the environmental causes are high fluoride levels in naturally flowing water, soil, and vegetables; high altitudes and chemical contamination of the environment from industries and fertilizer use in agriculture; and the degassing of volcanoes. Similarly, many of the cultural causes of high fluoride levels are linked to food culture and the type of foods consumed by a population. Such food items generally found to be linked with fluorosis in the literature are brick tea, zanba, roasted corn and chili, injera, milk, and vegetables.

However, all previous studies were conducted in populations living at high altitudes, or in communities prone to volcanic degassing far from Nigeria in Western Africa. The different food cultural practices and environments make generalization of these findings difficult to apply to the present study population. The one study that looked at the prevalence of dental fluorosis in Nigeria was carried out in an urban setting and did not look at cultural and environmental practices that predispose children to fluorosis. Therefore, it is clear that there is paucity of literature on the subject in this region and present study seeks to fill this gap in knowledge.

Chapter 3: Research Methods

Introduction

The purpose of this quantitative, cross-sectional study was to examine the cultural and environmental determinants of dental fluorosis among children in the Zing local area, a rural settlement in northern Nigeria. This chapter describes the methods that were used to examine the relationship between the development of dental fluorosis in children and the cultural practices and environmental exposures in one rural area in Nigeria. The chapter covers the following topics: the variables studied, the type of study design, the study population, the procedures for the study, the instruments that were used for data collection, as well as how the data were collected.

Institutional Review Board Approval

An institutional review board (IRB) approval for the conduct of the study was given in March 2016 with the following approval number, 02-03-16-0173727. The study was conducted between May 2016 and the end of June 2016.

The Study Variables

The study variables were the severity of childhood dental fluorosis as a dependent variable; the factors associated with oral health operating at the child, family, and community levels (such as the fluoride content of the water, soil, and common food types in the community) were the independent variables. Other independent variables included, local practices, such as household use of clay material and farming on hilly sites. Dental caries and SES were looked at as covariates.

The Study Design

This quantitative, cross-sectional survey involved three separate surveys. The first assessed the severity of dental fluorosis in children in the study area; the second sought to understand family and neighborhood influences on childhood fluorosis; and the third was administered to community leaders. The purpose of these surveys was to help answer the eight research questions listed in Chapter one.

A quantitative cross-sectional survey design was adopted to enable the assessment of an association between variables. Usually, quantitative designs are used to find causal associations (Creswell, 2009) but since this study was an exploratory one looking at associations between variables that have already occurred, no manipulation of variables were required as would be in experimental or quasi-experimental designs. Thus, this cross-sectional design allowed me to establish an association between the variables under study.

Methodology

Study Participants

The study participants who completed the first survey were children aged 5 -15 years, both male and female, of Mumuye ethnicity. The children were drawn from eight regular public primary schools out of the 92 primary schools existing in the study area (Taraba State Ministry of Education, 2014). The schools chosen by systematic random selection of every 12th school were the, Ibrahim Sambo, Sabongari, Dangong, Bitako, Yonko, Tadovah, Panki and Kwapo Gida Primary Schools. These were all regular public schools with good populations (an average of 360 students) and were located in either the rural or urban part of Zing.

The sample of students was selected by a systematic random selection of every third pupil whose parents provided consent and who met the selection criteria in each of the six grade levels at each of the schools. In this way, at least four pupils were selected from each grade level across the eight schools in the study area. This ensured that at least 24 pupils were selected from each school for a total sample population of not less than 192.

The second survey was administered to parent/guardian of each child enrolled in the survey preferably the parent who was able to communicate clearly with the researcher. In this way, family-level and neighborhood-level influences on childhood fluorosis were explored.

The third survey was administered to community leaders to gather information on community social amenities and cultural practices that influence childhood fluorosis. The participants were a local government council chairman who oversees the local government structure, the traditional council leader who is the custodian of the traditional customs and practices of the community, and all the school heads. In this way information on community influences on childhood fluorosis could be explored.

All surveys were administered in English with help from a capable community leader.

Inclusion and Exclusion Criteria

Participants were school children aged 5 to15 years, who had been born and raised in the community. The inclusion criteria for the selection of parents/guardian, was based on their children being selected as participants for the study. The criteria for inclusion in the third survey was that the participant was either a chairman of the local government council, head of a traditional institution, or the head of a participating school.

The Sample Size

The sample size for the study using a statistical power of 80% and an alpha level of .05 (95% CI) with an effect size of 0.3 for a small to medium effect (Cohen, 1998) was 176 (using a "*t* test" for two independent samples). However, an additional 25% was added to make up for attrition, bringing the sample size to 220. This sample size was for the children.

Instrumentation

The study utilized the following survey instruments:

1. A validated survey questionnaire administered in English (see Appendices B and C). This questionnaire was specially developed using the 22 domains of influences on children's oral health in the population health conceptual model (Fischer-Owen et al., 2007).
2. WHO/FAO procedure for analyzing chemicals, specifically the National Institute for Occupational Safety and Health (NIOSH)-and EPA-recommended procedure for estimating fluoride in biological materials and environmental samples (ATSDR, 2013). These organizations recognize the use of ion selective electrodes as a potentiometric method and the colorimetric (spectrophotometric) method for detecting fluoride levels in both biological and environmental samples.
3. The TSIF. This is a clinical scale that was used by the dentist (research assistant) to grade the severity of the dental fluorosis. This scale was used successfully in

surveys in past studies (Horowitz, 1986). This scale ranges from 0 to 6 (Table 2, Appendix A).

4. Dean's fluorosis scale (Table 1) was used to grade the severity in conjunction with the TSIF index.

To ensure content and empirical and construct validity of the questionnaire, the questionnaire was examined to see if all relevant variables of interest were covered by looking at and aligning the variables to the research questions. Thus, the questionnaire was checked to see if the content identified the intended variables and if it was capable of measuring these variables (Yaghmaie, 2003). Normally, this is done by looking at the relevance of the items in the questionnaire, as well as their clarity, simplicity, and unambiguity (Yaghmaie, 2003). To ensure empirical validity, it is important to know how an instrument measures an outcome correctly. Here, the predictive validity was used; this involved being measured by an external criterion (Frankfort-Nachmias & Nachmias, 2008) to predict how well it could measure an outcome event that was external to it. Two steps were used. First, the concurrent criterion-related validity was assessed by measuring the fluoride content of water and relating it to the severity of dental fluorosis. The second step was to ascertain the correct classification of fluorosis by the dentist using the TSIF by repeating the dental examinations of some participants without the knowledge of the dentist and comparing the scores. The construct validity of the study was determined by assessing the applicability of the survey instrument to the way of life in the community and whether there was need to adapt any of the questions.

However, the reliability of the questionnaire was assessed by conducting a pilot test of the questionnaire in a similar population (a group of pupils aged 5 to 15 years) to ascertain if they understood and could respond to the questions. Teachers in the schools were ask to provide feedback on the appropriateness of the survey instrument and if the pupils answered the items on the questionnaire correctly.

The appropriate scale and indices used for quantifying measures in the questionnaire were an attitude index and Likert scale. An attitude index is used to test the general knowledge of a problem, while the Likert scale can be used to quantify the grading of measures.

The reliability and validity of measurement instruments (i.e., the ion-specific electrode potentiometer, and the spectrophotometric method for measuring fluoride levels in foods, soil, and water, and the TSIF scale for grading fluorosis) have been tested by previous researchers in similar environments (Cao et al., 1997; Horowitz, 1986; Kahama et al., 1997; Paul et al., 2011).

Generally, ATSDR (2013) indicated that ion-specific electrodes can detect fluoride levels up to 0.1 mg/l with 95% recovery in urine samples(NIOSH, 1994); up to 0.1mg/l in water samples (EPA, 1998); up to 0.1µg/l with 97% recovery in food/beverage samples (Lopez & Navia, 1988); up to 0.2 to 0.5µg/g with a 54 to109% detection limit in milk, peas and pears (Debeka & Mckenzie, 1981); and 0.05 µg/l with more than 95% detection limit in vegetation (Jacobson & Heller, 1971). The spectrophotometric method can detect fluoride levels up to 0.1mg/dl in water (EPA 1998) and up to 1µg in tea, cocoa, tobacco, food beverages (Kakabadse, 1971).

Laboratory Investigations/Tests

The study used the Zirconium-Alizarin spectrophotometric method which is readily available in Nigeria for estimating the fluoride levels in both the biological and environmental samples. The test was conducted in collaboration with the Project Development Institute (PRODA), an institution of research and learning. The procedure involved the following steps for preparation of each of the specified samples: (a) Standard fluoride solution: 1.5013g ammonium hydrogen difluoride ($NH_4F.HF$) was weighed and dissolved in distilled water and diluted to 1 L. The solution contained 1,000mgL-[1] fluoride. A serial dilution of the stock solution was then prepared in the range 20.0, 40.0, 60.0, 80.0, 100.0, 120.0, and 140.0 mg/l; (b) Zirconyl-alizarin reagent: 300 mg of zirconyl chloride octahydrate ($ZrOC_{12.}8H_2O$) was dissolve in 50ml distilled water contained in a1 L glass stoppered volumetric flask; 70mg of 3-alizarin sulphonic acid sodium salt (also called alizarin red S) was dissolved in 50 ml of distilled water and poured slowly into the zirconyl solution while stirring, the resulting solution cleared up on standing for a few minutes; (c) Mixed acid solution: 101 ml of concentrated Hydrochloric acid (HCL) was diluted to approximately 400ml, with distilled water; 33.3 ml concentrated Sulphuric acid ($H_2SO_{4)}$ was carefully added to approximately 400ml distilled water, after cooling, the two acids were mixed; and (d) Acid-Zirconyl-Alizarin Reagent: The mixed solution was added to the clear zirconyl-alizarin reagent in a 1L volumetric flask and then distilled water was added to the 1L mark and mixed. The reagents changed in color from red to yellow within an hour.

The procedure continued by doing the following: (a) A series of standard solutions were prepared by diluting 1 ml of various volumes of standard fluoride solutions as prepared above with 100 ml distilled water in flasks or tubes, the range fell between 0 and 1.4 mg/l; (b) To 50 ml of each standard solution, 10 ml mixed acid zirconyl- alizarin reagent was added; (c) The spectrophotometer was set to a wave length of 570 nm; (d) The spectrophotometer was adjusted to zero absorbance with the reference solution i.e. distilled water with a reagent; (e) A plot of the concentration along x-axis and absorbance along y-axis was then carried out to obtain a calibration curve; (f) 50 ml of the sample and 10 ml of the mixed acid-zirconyl-alizarin reagent were added and mixed well; (g) The solution was then placed in the spectrophotometer, and the absorbance read; (h) By referring to the calibration curve, the concentration for the observed absorbance was read out; and(i) The procedure was then repeated with the diluted samples.

Procedures for Recruitment, Participation, and Data Collection

The procedures for recruitment of participants and the various steps involved in the recruitment process are as outlined in table 3.

Table 3
Participant Recruitment Procedures

Participant recruitment and data collection steps	Duration	Exact Location	Communication format (e.g., email, phone, in person, Internet)
Step 1			
I obtained prior permission from the State's Ministry of Education to conduct research using school children in the study area.	20days	Taraba State Headquarters, Jalingo	Email and follow up in person
Step 2			
I approached the school heads of the individual primary schools in the study area to explain my intention to conduct a study and requested permission to attend the next monthly parents teachers pupils	10days	Zing	In person.

(table continues)

forum (PTA). This provided me with the opportunity to notify parents, teachers, and pupils that a study was to be conducted, as well as what the study was about, and to request cooperation of all parents whose children would later be selected to participate in the study (Appendix F).			
Step 3			
I then systematically selected every third pupil from each of the grades during class roll call (i.e., from the class register) to meet in the school assembly hall together with their parents to orientate them on what the study was and to agree on the timing for the conduct of study. I explained that participation would be voluntary and that it would take after school hours. I also explained the procedure for selecting participants, how the study would be conducted, and some aspects of the study that will be repeated (i.e., dentist inspection of teeth), pointing that this activity was not going to affect school day activities. I explained that the study was important as it could provide information about the students' oral hygiene. I explained the informed consent process, asked if they were willing to participate, and informed them that each parent/guardian participant was required to fill a consent form and the students had to fill out an assent form after reading them carefully. The completed forms were to be returned to	10days	8 primary schools	In person.

(table continues)

me in the school assembly hall within 2 weeks if they were willing to participate in the study.			
Step 4 I then proceeded to visit the chairman, secretary and head of the Department of Works in the Zing local government secretariat explaining what this study was about and that they were invited to participate because they were needed to provide information on community influences that could impact tooth discoloration. To show their readiness to participate, they were required to give consent after reading through the consent form.	1day	Zing Secretariat	In person
Step 5 I proceeded to open a register to enable me receive and record all returned parent consent forms and pupil's assent forms for the period of 10 days, noting also all addresses. The received consent forms were immediately placed in locked boxes provided for that purpose.	10 days	School hall	In person
Step 6 While continuing with Step5, I pilot tested the survey instrument at a nearby primary school to ascertain how correctly participants answered the questions before I proceeded with the study in the study population.	5 days	1 primary school premises	In person

(table continues)

Step 7 After pilot testing the survey tool in Step 6, I invited all selected pupils whose parents provided consent (after establishing timing with the head teacher to be after school hours) and requested verbal assent to participate because they were children.	7days	School premises	In person
Step 8 I proceeded to enroll all the pupils meeting the selection criteria (aged 5 to15years and Zing resident) according to their class grade to participate in the study.	10days	School premises	In person.
Step 9 I invited all enrolled pupils and their parents at the next PTA forum to participate in the study and briefed them on confidentiality of information to be given and answered any further questions that arose relating to any dangers pose by the study. I highlighted that they were free to decide to participate or not to participate in the study. If, however, they volunteered to participate, then they were required to answer the questions on the questionnaire. They were also told that the study had only minimal risks, which were mainly the psychological stress of exposing their teeth to be inspected as well as answering questions on food types and	3days	1 classroom	In person

(table continues)

water sources they commonly used.			
Step 10 I then enrolled all parents of enrolled pupils (i.e., mothers, fathers, guardians) in the study.	3days	1 classroom	In person
Step 11 I administered survey Questionnaire 1 in English to the student participants in one classroom to maintain confidentiality. I informed the students that some of them would be inspected twice by the dentist.	10 days	1 classroom	In person.
Step 12 At the same time, I administered survey Questionnaire 2 in English to the students' parents/guardians in another classroom to maintain confidentiality.	10 days	1 classroom.	In person.
Step 13 I invited the dentist to carry out a visual inspection of the students' teeth in my presence using day light in a secluded space one at a time. This was done by asking the student to open his/her mouth for the dentist. Once this was complete, I recorded the assessment.	10 days	1 classroom	Dentist/researcher
Step 14 I arranged for repeat observations of every 10th participant by the dentist to ascertain validity of the	3 days	1 classroom	Dentist/researcher.

(table continues)

measurement (the Cronbach's alpha presented in Table 4 and Appendix H, showed a reliability coefficient of 0.948, indicating good reliability).			
Step 15 I then rewarded each participant with a biro worth#100(about $1) for participating.	5 days	School premises	In person.
Step 16 I enrolled all identified community leaders (i.e., heads of participating schools, the local government chairman and secretary, and the head of local government works/estates department).	2 days	Zing Community	In person.
Step 17 I administered Questionnaire 3 to community leaders in their offices.	5 days	Zing community	In person
Step 18 I collected samples from water sources, soil, and food (bambara, dawa, and vegetables) identified in the study area for biochemical analysis of the fluoride content by the research institute.	3 days	Zing community	In person and one assistant from the institute.(The assistant from the research institute only helped with ensuring that samples were collected properly since it was the institute that analyzed the fluoride content in these samples. The institute needed to be involved at this stage to ensure that proper standards were maintained in the collection process. I paid for these services

	since the institute needed to procure chemicals for the analysis. See the letter of acceptance to analyze from the institute. The institute's only task was the fluoride content in the samples. Further analysis of the findings was my task. This information helped me answer RQ 7).

Data Collection

The survey was administered face to face to the participants in English. To help collect data, I engaged one research assistant, one dentist, and one assistant for the sample analysis. The dentist was a dental officer at nearby the Federal Medical Center in Jalingo, Taraba, the state capital. He used the Dean's fluorosis index and the TSIF scale to grade the severity of fluorosis (Appendix D and E).The other two assistants worked with the planning and statistic unit of the independent electoral commission in Taraba and the research institute (PRODA). All the helpers were oriented on study procedures, data collection procedures, eligibility to participate, administration of the consent form, and proper administration of the survey questionnaire.

Consent to Participate in the Study

All children participating in the study were required to give verbal assent and consent signed by their parents, while the adults had to show willingness to participate by signing a written consent (Appendix Z, 1- 5). The study procedures were explained to the participants, highlighting the advantages of participating and the need to give consent.

Since the study was non-invasive, the participants were advised that the study had only minimal risk.

Data Collected

The study collected the following data using the developed questionnaire: (a) participant identification (name, sex, age, place of residence, time of residence, and address of residence); (b) socio-demographic data (types of water sources in community, number of primary and secondary institutions in community, major occupation in community, community's source of income).

Information on the study variables such as: (a) household practices (both single-parent or and two parent households); (b) form of water storage (clay pot or not), and cooking methods (clay pot or not); (c) food items consumed in household (dawa, bambara, yam, etc.); (d) food cultivation/farming(site-hilly or not), use of fertilizer in farming; (e) tooth fluorosis (Do you consider your teeth discolored? How long have you noticed these changes?, How do you feel about having discolored teeth? How often do you brush your teeth? What do you do to maintain oral hygiene?); (f) food culture, including common food types consumed (dawa, bambara, yam, vegetables, etc.), and how often they are consumed (not often, often or very often); (g) water use (source of your drinking water, amount drunk daily, any times that this quantity changes); and the environment for food cultivation (around mountain heights, level ground, valley, etc.), and what common food are cultivated.

Clinical examination of participants involved doing the following: (a) TSIF score of participant's teeth; and (b) identifying signs of dental caries. Furthermore, laboratory estimation of fluoride using the spectrophotometric method was performed on the following samples from the community: (a) water specimens from common water sources, including borehole, streams, etc., in the community; (b) chosen food items eaten in the community, such as vegetables, yams, and tea; and (c) soil specimens collected from common farming locations in the community

Data Analysis Plan

I started the data analysis process by collating, sorting, and coding the data points generated from the survey questionnaire. Using the SPSS, Epi info, and Winpepi software as statistical tools for analysis, I input all the variables in the study for each participant, such as age, sex, period of residence in the community, eats dawa, eats bambara, water source, occupation of parents, household size, and severity of dental fluorosis.

I then proceeded with the following steps. For the descriptive statistics, I presented the characteristics of the study population in frequency tables and graphs. I used the central tendency measures to determine the mode, mean, and the median of the study population. Considering that this study involved mostly categorical variables, frequency count, percentages, and charts were used to present the data. For measures of association, a chi-square statistic non parametric (distribution-free) tool designed to analyze group differences when the dependent variable is measured at a nominal level (i.e., categorical data) was used for tests of association. I presented this information in histogram, pie charts, and tables.

To enable me to answer the research questions and related hypotheses, I carried out the statistical tests describe below.

Hypothesis 1: The prevalence of dental fluorosis in children 5 to 15 years of age in the Zing community is high when compared with the standard TSIF scale developed by Horowitz in conjunction with Dean's fluorosis scale.

Hypothesis 2 to 6: There is a positive association between dental fluorosis and the variables of dawa consumption by children, bambara consumption by children, use of clay pots by households, cropping on hilly sites, and use of fertilizers in farms.

I used the chi-square test to analyze if there were statistical associations in order to make inferences. I wanted to assess how the dependent variable (i.e., fluorosis) occurred in the population of children in Zing and if this presence was associated with any factors (i.e., independent variables). The test allowed for evaluation of both dichotomous independent variables and of multiple group studies (Green & Salkind, 2011) and to test if this was statistically significant $p<0.05$.

The assumptions for testing the hypotheses were (1) the two variables should be measured at an ordinal or nominal level (i.e., categorical data) and (2) the variables should consist of two or more categorical independent groups. To comply with the underlying assumptions I ensured that both the dependent and independent variables were measured at a nominal level. I made sure that the value in the cell expected was not less than 5 in at least 80 % of the cells and that no cell had expected of less than 1.

Hypothesis 7: There is positive association between the severity of fluorosis and the level of fluoride in water, foods, and soil

I used the Pearson correlation (regression analysis) test to test the strength of the association. A positive association is considered if the value is above zero, and a negative association is considered if it is less than zero. There is a low positive association if the correlation coefficient is between 0.1 to 0.3, moderate severity if the coefficient is between 0.4 to 0.6, and high severity if the coefficient of correlation is 0.7 and above. If, however, the correlation coefficient is negative, then there is no association.

For this study, the underlying assumption was that the interval or ratio level (i.e., continuous measures) was used, that there was a linear relationship between the measures and normally distributed bivariate measures. This was ensured by measuring the content of fluoride in the water, food, and soil using the interval level measures and presenting the findings in a scatter plot (Figures 11, 12, and 13). There was one outlier in the soil sample. This was then correlated with the TSIF measure (ranging from 0 to 6) used by the dentist to ascertain if a correlation existed.

Hypothesis 8: Children's dental caries and family SES status are not potential confounders in the study outcome.

I used the Chi square and ANCOVA tests to analyze the impact of dental caries in children and family SES on the study outcome. The homogeneity of slopes assumption is required for using the ANCOVA test. This is assured with each individual or case with scores on the three variables; i.e. a factor or independent variable, a covariate, and a dependent variable.

Summary

This was a quantitative, cross-sectional study designed to examine the cultural and environmental determinants of dental fluorosis in children in a rural community in Nigeria. Three surveys were administered. The participants for the first survey were children aged 5 -15 years, drawn from eight regular public primary schools in the study area. The second survey was on parent/guardian of each child enrolled in the first survey, and the third survey was on community leaders to gather information on community social amenities and cultural practices that influence childhood fluorosis.

The sample size for the study was 176 based on "*t* test" table and the study participants were selected through systematic random selection from each of the six grades in the selected schools. The survey instruments were assessed for reliability, and the procedure for participant recruitment and data collection was as outlined in table 3.

Data analysis was done using the SPSS, Epi info and Winpepi statistical tools. The results of the analysis are as presented in chapter 4.

Chapter 4: Results

Introduction

The purpose of this quantitative, cross-sectional study was to examine the cultural and environmental determinants of dental fluorosis among children in the Zing local area, a rural settlement in northern Nigeria. The purpose of this chapter was to present the study findings as they address each of the research questions and hypothesis established in Chapter 1. These research questions were as follows:

1. What is the prevalence of dental fluorosis among children aged 5 to 15 years in the Zing community?
2. Is there an association between the presence of fluorosis among children in the Zing community and dawa consumption by these children?
3. Is there an association between the presence of fluorosis among children in the Zing community and bambara consumption by these children?
4. Is there an association between the presence of fluorosis among children in the Zing community and use of clay pots by households?
5. Is there an association between the presence of fluorosis among children in the Zing community and cropping on hilly sites?
6. Is there an association between the presence of fluorosis among children in the Zing community and the use of fertilizers for farming?
7. Is the severity of dental fluorosis in children in Zing community associated with the level of fluoride in water, foods and soil?
8. Is children's dental caries or family SES status a potential confounder in the study outcome?

This chapter is organized as follows: (a) description of the sample; this section employs frequency, percentages, charts, means, and correlations to examine the children and parents or guardian characteristics; (b) examination of the research questions and testing of hypothesis; this section focuses on the inferential analysis using chi-square and regression analyses; (c) further exploratory investigation using the child health model to identify factors at the three levels (child, parent, and community) that could influence fluorosis in children. First, however, I offer a concise report on the pilot study conducted at the beginning of the study.

Report on the Pilot Study.

A pilot study was conducted in a different school using students aged 5 to 15 years and with some volunteer parents. The purpose was to ascertain if the participants could understand and respond correctly to questions in the survey instrument. The pilot study was held 2 days before the main study. A total of 30 participated (pupils and parents).

Survey 1: Students

Using the child interview questionnaire (Survey 1), the participating children were asked to answer the questions presented as correctly as possible. Their answers were then reviewed with each student. The outcome was as follows: Questions 1 to 6 were answered correctly, and Questions 7 and 8 required clearer explanations.

In response to this feedback, I had to classify SES status as follows: working in government or holding public office as high social class, working as a civil servant (e.g., teacher or office worker) as the middle social class, and subsistence farming or petty trading as low class. This grouping looked agreeable and reasonable to everyone, including the head teachers. Thus, to easily determine SES, Question 7 was reframed as "What is your parent's occupation."

Question 8; Do you eat breakfast, lunch, and dinner every day? required a definite answer, and thus yes/no was included. Questions 9 to 25 were clear and had clear answers. Questions 26 and 27 were answered by the dentist. Question 28 was answered by the dentist through recording observations using the TSIF and Dean' grading index, which also formed the measure for testing the validity of the measurement instrument, which was done by carrying out repeat grading of the pupil's teeth without the prior knowledge of the dentist. In this way, a measure of the validity of the diagnosis of fluorosis by the dentist was established as 84%. This was done by noting the number of repeat scores and comparing them with the earlier scores. In this case, 21 of the 25 repeat observations were consistently graded. The Cronbach's alpha test showed a reliability coefficient of 0.948 (Table 4, Appendix H).

For Questions 1 to 27, the reliability of the questionnaire was 92%, as the students could answer 25 of the 27 questions correctly. The correctness of the answers was validated by asking the teachers of the schools and their parents if the students had responded correctly to the questions. For example a student's stated age and place of residence or village were corroborated by teachers using school records. The parents corroborated information about specific topics, areas such as family occupation and family size.

Survey 2: Parents/Guardians

For the parent/guardian survey, 4 of the 29 questions administered needed clarification: (a) for Question 7, what is your family composition? participants were required to tick either single parent, reconstituted parents, or both parents living together. To clarify this, the question was explained as, Are you parents living together or not? In this way, the correct answer was given, (b) Question 8; what is your family size, was better as, how many of you live in your household?

Question 11, how long did you breast feed your child involved in this study, was better answered by asking parents to state the number of months the child was breastfed. Lastly, Question 29 was reframed to; do you use clay pot for storing water or cooking, yes/no. In this way, a definite response for the use of clay pots for storing water or cooking was obtained.

Impact of the Pilot Study on the Main Study

The impact of the pilot study on the main study was its contribution to the quality of responses received from the participants. It ensured that the questions administered received more definite answers. The changes in the form of the questions did not, however, affect the instrumentation and data analysis and strategies.

Data Collection for the Study

This was a field survey that involved the generation of primary data. It lasted from first the beginning of May 2016 to the end of June 2016. The first week was focused on the recruitment processes (i.e., explaining to the parents, teachers, and pupils that a study was being held and further addressing the selected participants). Then, consent and assent forms were administered to selected participants as outlined in the methods section. In this way, 281 pupils and parents gave consent to participate in the study.

The subsequent weeks included the administration of the questionnaires to the students and parents who returned their consent forms. The response rate was high. Of the 281 questionnaires issued for the student survey, 273 participated, while for the parent survey, 263 responded to the questions, accounting for 97% and 93.6% participation respectively.

There were no major discrepancies in the data collection plan from the plan presented in Chapter 3; however, to elicit the correct responses from the parents/guardians, the parent who could communicate freely and clearly with the researcher was preferred to be administered the questionnaire. This was different from the earlier envisaged plan, where preference would have been given to the mothers. In this way, 36% of responses were provided by the mothers and 63.6% by the fathers which may bias the responses. Because of the interest shown in the study, more participants were enrolled in the study than the sample size that was initially anticipated. This markup was used to help address the problem of attrition. Furthermore, the schools used for the study were named according to the names provided by the administrative heads of the schools, and these were slightly different from the names used in the primary schools sampling frame from where the schools were selected. Thus, the school names carry both names for ease of identification and uniformity.

However, during the data sorting and analysis stage, it was observed that 23 parents/guardians still needed to be contacted in order to provide complete information to their earlier non-responses. To do this, I first had to identify all those children whose parents did not return their questionnaires and then re-visit the field for a second time from January 10 to January 15, 2017, to gather the missing data. Thereafter, the criteria for the sample selection such as age and length of stay in the community for Survey 1and the corresponding parent/guardian for each student for Survey 2 was applied. In this way, 4 students were further dropped from the study for not meeting the criteria. Accordingly, analysis of the results was conducted on 269 children and their parents/guardian, for a total of 538 participants compared to the previous 273 children and 263 parents who returned their questionnaires.

Reliability of TSIF Grade

The validity of the TSIF grading by the dentist was evaluated using “Cronbach’s alpha” using the SPSS software, version 23, to ascertain the reliability of the dentist’s grading; i.e., whether it was capable of reproducing consistent or similar results. The results for the tests are presented in Table 4. The results show that the correlation coefficient was 0.948. According to Bulsara and Priya (2014), a common rule of thumb is 0.80 or higher for adequate reliability and 0.90 or higher for good reliability. Given this result, the grade is considered reliable for the study.

Table 4

Reliability Statistics

Cronbach's alpha	Cronbach's alpha based on standardized items	*N* of Items
0.948	0.948	2

Description of Sample

Frequency and Percentages

Student characteristics. Table 5 presents the demographic information for the student participants. The gender distribution shows that 136 (50.6%) of the respondents were male, while 133 (49.4%) were female. Based on age in years, 47 (17.5%) of the children were between the ages of 5 to 7 years, 99 (36.8%) between the ages of 8 to 10 years, 86 (31.9%) between the ages of 11 to 13 years, and 37 (13.8%) between the ages of 14 and 15 years. These age-related percentages are comparable across gender, mean age for male 10.6 ± SD 2.90 and for female 9.8 ± SD 2.60 (Figure 2, Appendix I). Regarding class levels, 29 (10.8%) of the respondents were in Grade 1, 37 (13.8%) were in Grade 2, 50 (18.6%) were in Grade 3, 48 (17.8%) were in Grade 4, 31 (11.2%) were in Grade 5, and 75 (27.9%) were in Grade 6 (Figure 3). On feeding, 185 (69%) of the respondents ate breakfast, lunch, and dinner daily, while 83 (31%) did not. These percentages were also comparable across gender (Figure 7, Appendix J and N). Regarding diet, 228 (84.8%) of the respondents ate dawa, while 41 (15.2%) did not, and 252 (93.7%) of the respondents ate bambara, while 17 (6.3%) did not. Regarding the frequency of eating dawa, 59 (21.9%) of the respondents ate dawa daily, 33 (12.3%) ate dawa weekly, 136 (50.6%) ate dawa, two to three times weekly, and 41 (15.2%) did not eat dawa at all. Also, 43 (16.0%) of the respondents ate bambara daily, 45 (16.7%) ate bambara weekly, 164 (61.0%) ate bambara two to three times weekly, and 17 (6.3%) respondents did not eat bambara at all. This implies that most people ate dawa and bambara two to three times weekly.

Furthermore, the table indicates that more of the children 99 (37.9) had lived in the community for 8 to 10 years.

Table 5
Children Characteristics

	Frequency	Percentage
Gender		
Male	136	50.6
Female	133	49.4
Total	269	100.0

(table continues)

Age in years		
5-7 years	47	17.5
8-10 years	99	36.8
11-13 years	86	31.9
14-15 years	37	13.8
Total	269	100.0
Class grade		
Grade 1	29	10.8
Grade 2	37	13.8
Grade 3	50	18.6
Grade 4	48	17.8
Grade 5	30	11.2
Grade 6	75	27.9
Total	269	100.0
SES		
High	3	1.10
Middle	57	21.20
Low	209	77.70
Total	269	100.0
Eats breakfast, lunch, dinner daily		
No	83	31.0
Yes	186	69.0
Total	269	100.0
Eats dawa		
No	41	15.2
Yes	228	84.8
Total	269	100.0
Eats bambara		
No	17	6.3
Yes	252	93.7
Total	269	100.0
Frequency of eating dawa		
Daily	59	21.9
Weekly	33	12.3
2 - 3 times weekly	136	50.6
None	41	15.2
Total	269	100.0
Frequency of eating		

(table continues)

bambara		
Daily	43	16.0
Weekly	45	16.7
2 - 3 times weekly	164	61.0
None	17	6.3
Total	269	100.0
Duration of Residence		
5 - 7 years	47	17.5
8 - 10 years	99	36.8
11 - 13 years	86	31.9
14 - 15 years	37	13.8
Total	269	100.0
Farm location		
Valley	39	14.5
Low land	169	62.8
Hilly site	22	8.2
None	39	14.5
Total	269	100.0
How do you clean your teeth?		
Toothpaste on brush	197	73.2
Chewing stick	62	23.0
Charcoal	2	0.7
Toothpaste on brush/chewing stick	6	2.2
None	2	0.7
Total	269	100.0
Taught oral hygiene in school		
No	26	9.7
Yes	243	90.3
Total	269	100.0
Diagnosis of Fluorosis?		
Yes	233	86.6
No	36	13.4
Total	269	100.0

Note: 4 students in class grades 1 and 5 were dropped during data sorting for not meeting criteria. Age-related percentages across gender differed significantly, mean (male, 10.63 ± 2.86; female, 9.88 ± 2.60), *p* value of 0.025 (Figure 2, Appendix I), Class grade-related proportions across gender were similar for male and female *p* value 0.10 (Figure 3, Appendix J), and there was no difference in percentage among gender for who eats breakfast, lunch, and dinner daily, *p* value 0.817 (Figure 7, Appendix N).

Figure 2 below presents a chart of the age profiles of the participants by gender

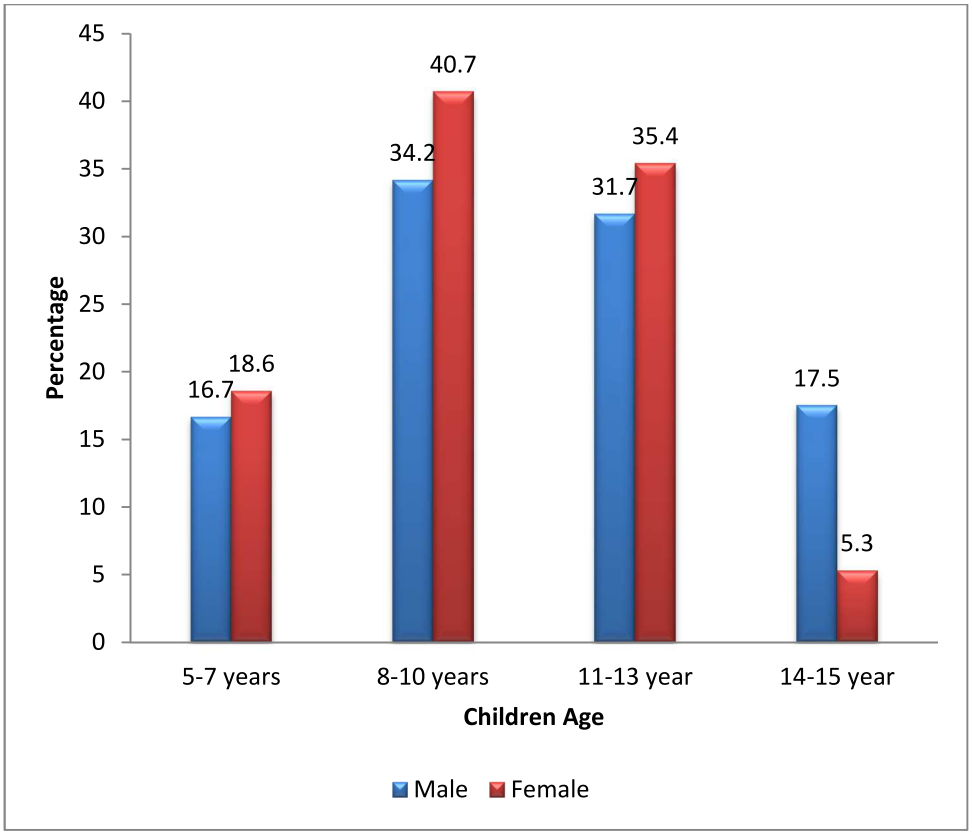

Figure 2. Age profile of participants by gender.

In Figure 2, it can be seen that the percentage across the various age groups were 16.7% male to 18.6% female in the 5 to 7 age group, 34.2% male to 40.7% female in the 8 to 10 age group, and 31.7% male to 35.4% female in the 11 to 13 age group but for the 14 to 15 age group, there were more males (17.5%) than females (5.3%). The fall in the proportion of females in the 14 to 15 age group can be explained by the custom of early marriage of the girl child. As for the very young 5 to7years old, there is still poor educational policy, and structural system that support the early education of this age group. However, the majority of the children were in the 8 to 10, and 11 to 13 age groups, and the percentages of both genders in these groups were 65.7% male to 76.1% female.

An independent sample *t* - test shows that the mean age of children in the study was male (10.63 ± SD 2.86), and female (9.88 ± SD 2.60). This was significant at a *p* value of 0.025 (Appendix I) and indicates that the male students were slightly older than the female students.

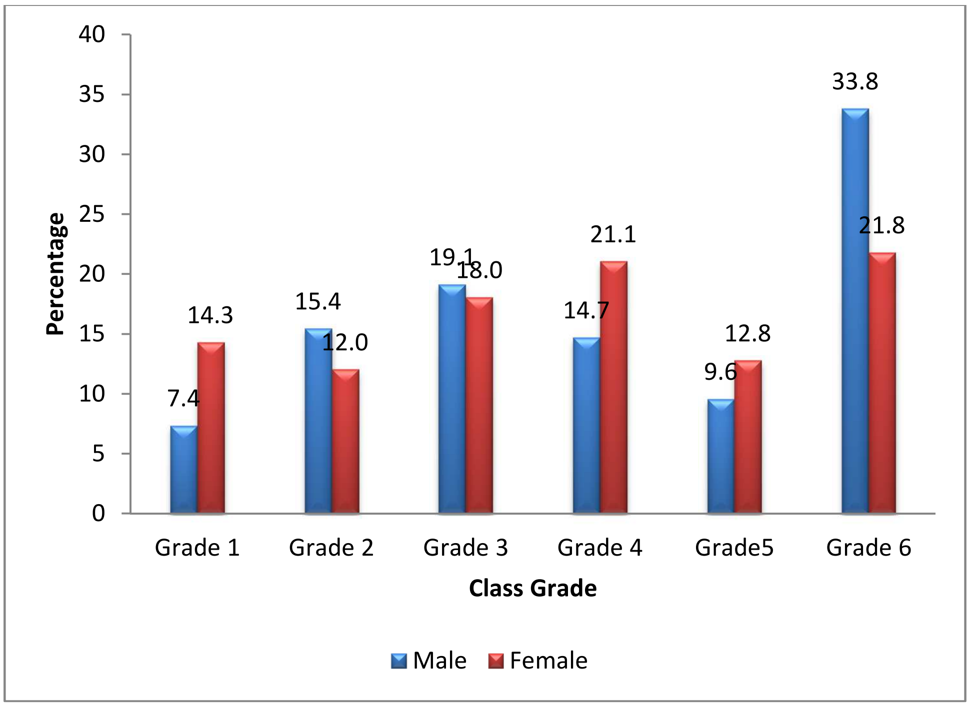

Figure 3. Gender characteristics according to class grade.

In Figure 3, it can be seen that the gender gap across Grades 1 to 6 is the same as it is complimentary. This is because the sum of the proportions for males across grades 1 to 6 is the same with that of the females. The sum of proportions for males across grades 1 to 5 is 66.2%, while the sum for the proportions of the females across grades 1 to 5 is 78.2%. The difference between females and males (ie 78.2% minus 66.2% which is 12.0%) is the same with the gender gap of 12% found in grade 6. However, a Pearson chi-square test of these class gender characteristics were not statistically significant at *p* value of 0.10 (Appendix J) indicating that there was no significant difference between gender distributions across the grades.

Figure 4 below, presents the relation of gender characteristics with choice of treatment by the students.

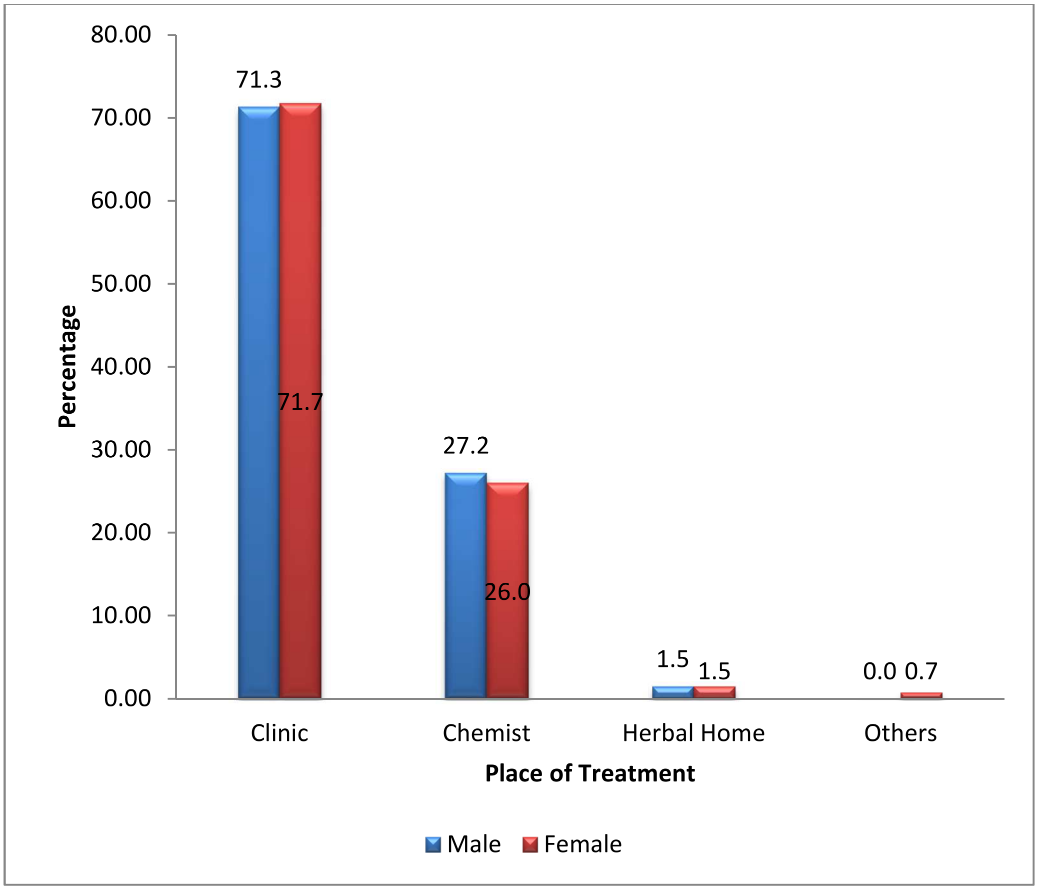

Figure 4. Gender characteristics with choice of treatment.

In Figure 4, the percentage of male that used health clinic was 71.3%, and that of female was 71.7%. The percentage of students who used health clinic was more when compared with those using the chemist (27.2% male, 26.0% female), herbal home (1.5% male, 1.5% female) and others (0.0% male, 0.7% female). Their choices was however, not statistically significant with exact fisher test value of *p* 0.683 (Appendix K) which indicates that there was no significant difference between males, and females in the methods they choose when seeking for treatment. This may be explained by the fact that their choices were limited by the methods available in the community.

Figure 5, summarizes student's preferred mode of cleaning teeth.

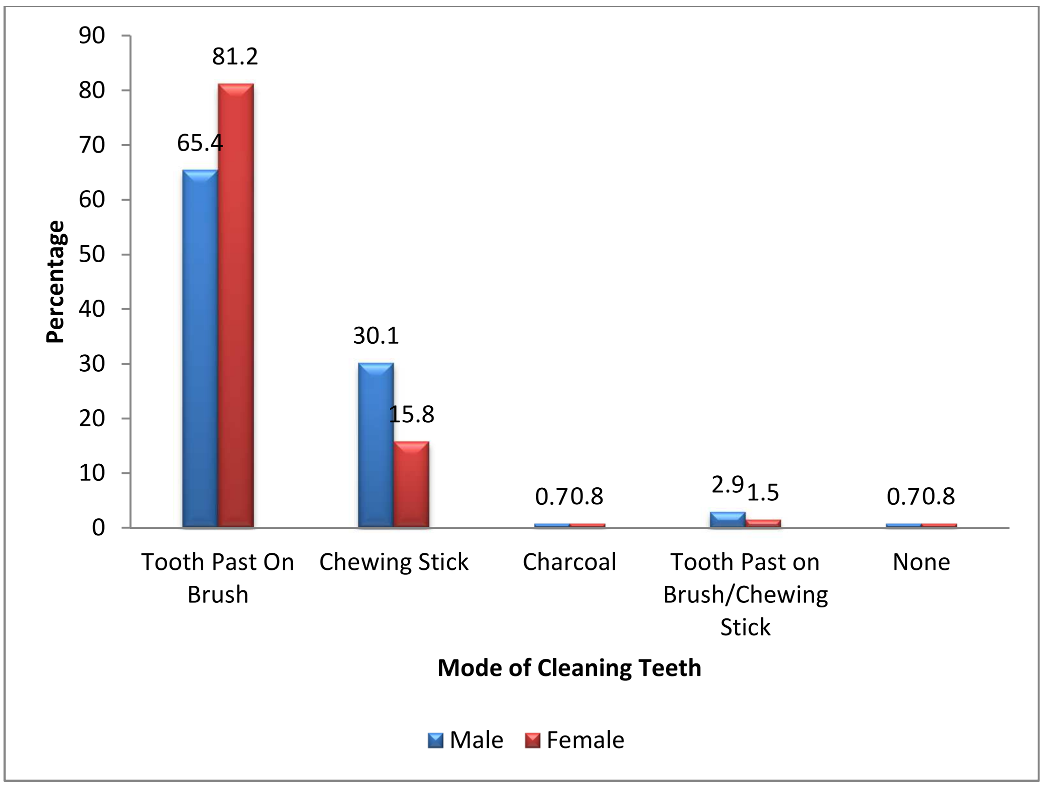

Figure 5. Student's preferred mode of cleaning teeth

In Figure 5, it can be seen that 65.4% of the male children, and 81.2% of the female children used toothpaste and a brush. This was followed by 30.1% male, and 15.8% female who preferred using chewing stick to care for their teeth. These student's choices for cleaning teeth was significant with exact fisher test of $p = 0.0239$(Appendix

L), indicating that there was significant difference between the gender in the methods used in cleaning teeth.

Figure 6 below, shows whether children were taught hygiene in school.

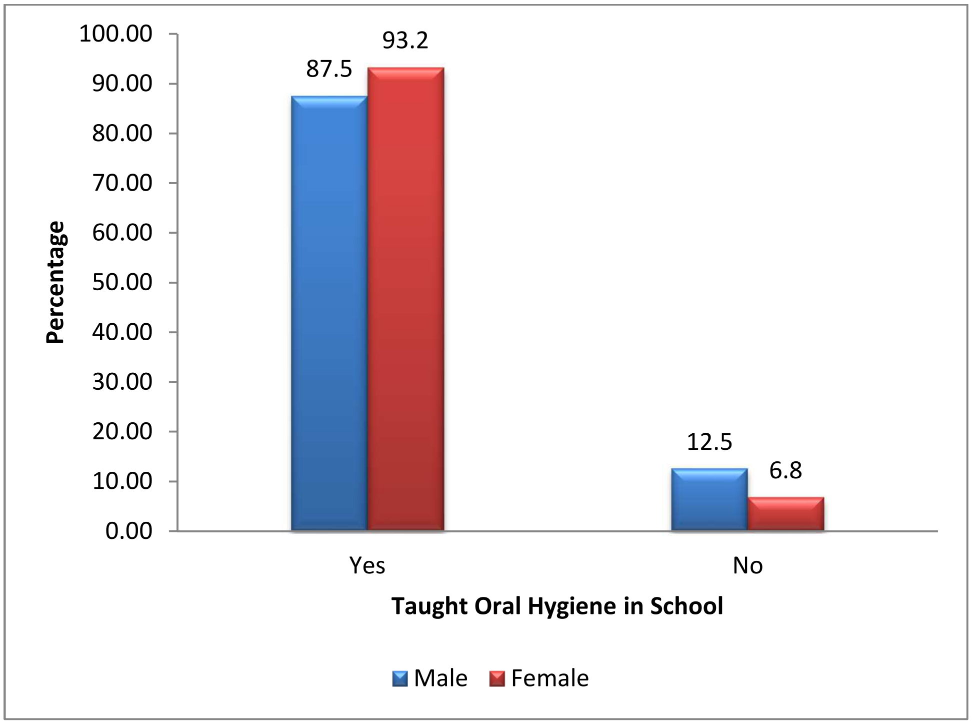

Figure 6. Children taught oral hygiene in school.

In this figure, it can be seen that 87.5% of the male children and 93.2% of the female children indicated that they were taught oral hygiene in school. While 12.5% of the male and 6.8% of the female children indicated that they were not taught oral hygiene. An independent t – test mean of children taught oral hygiene was 1.132 ± SD 0.34, while the mean of children not taught oral hygiene was 1.182 ± SD 0.39. The p value was 0.517, indicating that there was no significant difference between the gender on being taught oral health in school (Appendix M).

Figure 7, presents the gender ratio for which students eat breakfast, lunch, and dinner daily.

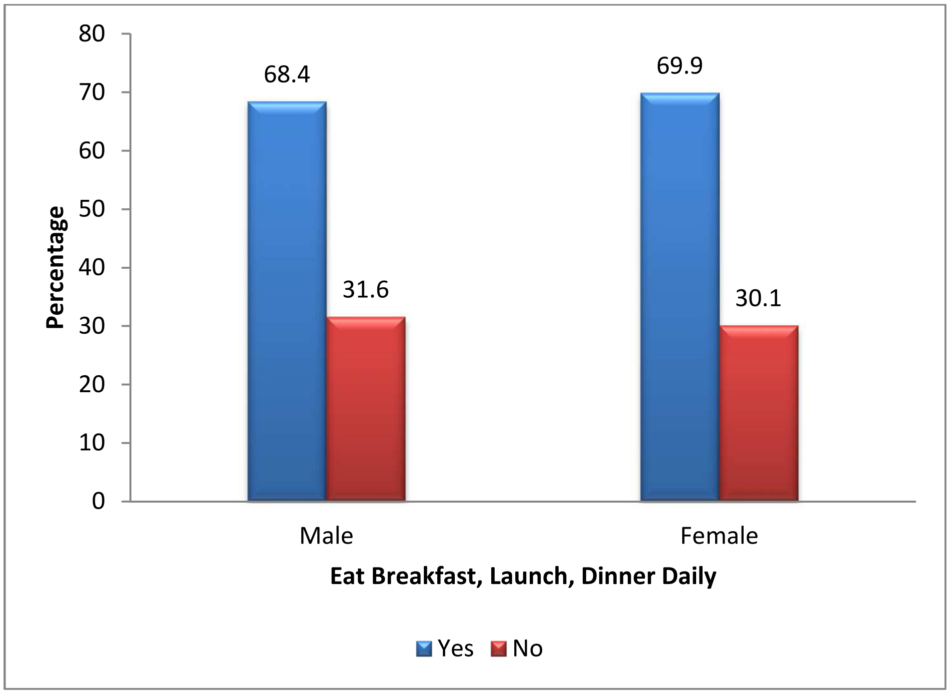

Figure 7. Gender ratio for students feeding.

This figure shows a similarity among the two genders regarding which students eat breakfast, lunch, and dinner daily and also those who do not. The independent *t* – test mean of children who ate breakfast, lunch and dinner daily was male 1.482 ± SD 0.50 and female 1.497 ± SD 0.50. This was however not significant at a p=0.817 (Appendix N), indicating that there was no significant difference between the students as regards feeding.

Figure 8, presents the diagnosis rate of fluorosis in the study population.

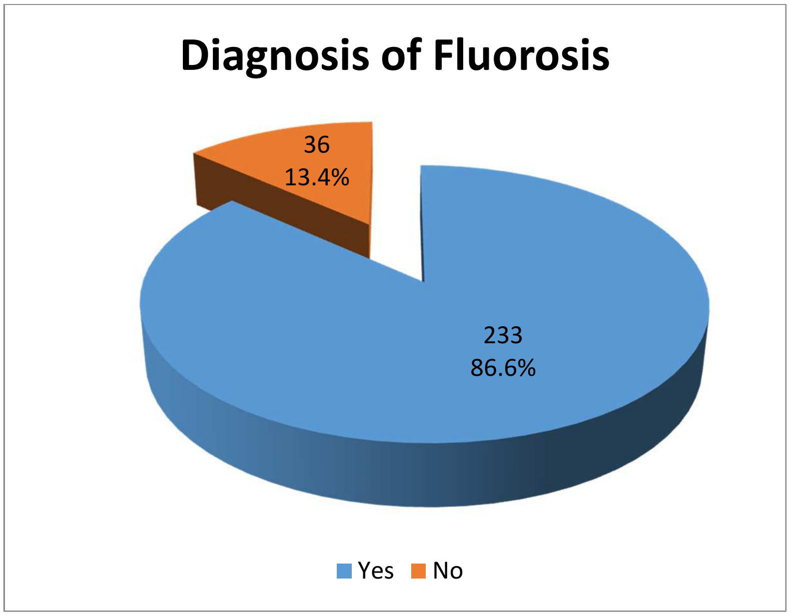

Figure 8. Diagnosis rate of fluorosis in the study population.

From this figure, it can be seen that the prevalence of fluorosis in the students in the study area was 86.6% and, those without fluorosis accounted for 13.4%. The mean age of children with fluorosis was 10.20 ± SD 2.68, and those without fluorosis was10.80 ± SD 3.22. This was not statistically significant at *p* value 0.181 (Appendix O), indicating that there was no significant difference in the age of those children with fluorosis and those without fluorosis. However, the difference between children having fluorosis and those without fluorosis may be caused by the length of stay in the community, the age of the student, family SES, student's attitude to health, and the student's knowledge of illness; p= 0.031, 0.027, <0.001, and <0.001 respectively (Tables 19, 22, 23, and 24 below).

Figure 9 below, demonstrates the fluorosis diagnosis rate by gender.

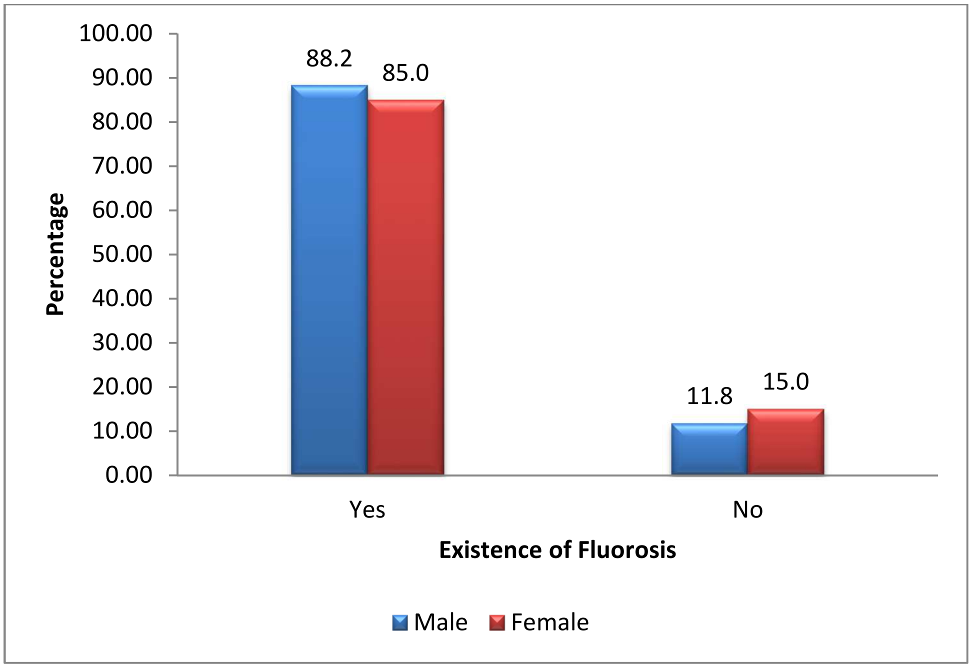

Figure 9. Fluorosis diagnosis rate by gender.

Figure 9 shows that majority of both males and females were found to have fluorosis. The proportion of diagnosis of fluorosis and gender from the figure is male with fluorosis 88.2% (without fluorosis 11.8%) and female with fluorosis 85.0% (without fluorosis 15.0%). The independent *t* –test of the mean of fluorosis diagnosis was male 1.118 ± SD 0.3234, and for female 1.150 ± SD 0.3588. However, there was no statistical difference between the genders in the diagnosis of fluorosis, p=0.432 (Appendix P), indicating that both gender were similarly affected.

Similarly, Figure 10 presents the proportion of fluorosis among children by age group and gender.

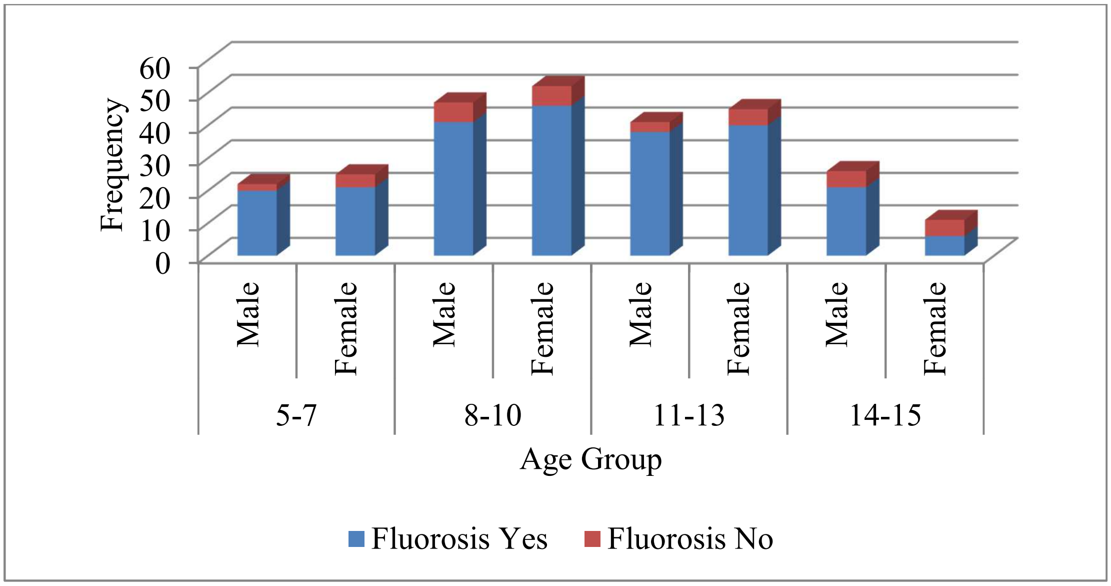

Figure 10. Proportion of fluorosis by age group and gender.

Figure 10 shows that the age group with the highest proportion of fluorosis was the 8 to10 years-old followed by the 11 to13 years-old. This means that 70.8% of the children diagnosed with fluorosis were between the ages of 8 to13 years. There is no statistically significant difference between the mean age of children with fluorosis (10.20 ± SD 2.68), and those without fluorosis (10.80 ± SD 3.22) with *p* value 0.181 (Appendix O).

The Figure further shows that fluorosis was similarly distributed across genders, although there was a slight female preponderance (i.e. female 107, and male 99) in the 5 to13 year-old age range and a slight male preponderance (male 21, and female 6) in the 14 to15 year-old range. The mean of fluorosis diagnosis was 1.118 ± SD 0.3234 for male, 1.150 ± SD 0.3588 for female, and there was no significant statistical difference between the gender in the diagnosis of fluorosis, p=0.432 (Appendix P).

Parents/guardians characteristics. Table 6 depicts the information on the parents of the sampled children. The gender distribution shows that 171 (63.6%)

respondents were male, while 98 (36.4%) were female. 1 (0.4%) respondent was less than 11 years of age, 6 (2.2%) respondents were between 11 to 20 years of age, 63 (23.4%) respondents were between 21 to 30 years of age, 88 (32.7%) respondents were between 31 to 40 years of age, 81 (30.1%) respondents were between 41 to 50 years of age, 24 (8.9%) respondents were between 51 to 60 years of age and 6 (2.2%) were above 60 years of age. The family composition distribution showed that 230 (85.5%) respondents had both parents living together, 4 (1.5%) were reconstituted parents, while 30 (11.2%) were single parents and 5 (1.9%) did not respond.

Based on household size, the table reveals that 63 (23.4%) respondents had households of less than 6 people, 148 (55.0%) respondents had households between 6 to 10 people, 30 (11.2%) respondents had households between 11 to 15 people, 12 (4.5%) respondents had households of 16 to 20 people, 7 (2.6%) respondents had households between 21 to 25 people, 3 (1.1%) had households between 26 to 30 people, while 6 (2.2%) were above 30.

Regarding religion, most of the respondents (88.8%) practiced Christianity, followed by those who practiced Islam (16.7%). This table also reveals that 239 (82.9%) respondents ate family meals together, while 30 (11.2%) did not eat family meals together. Based on household highest level of education, the table shows that 56 (21.9%) respondents had degrees, 3 (1.1%) had a diploma or NCE, 138 (51.3%) had completed secondary education, 32 (11.9%) had completed primary education, and 3 (1.1%) had no formal education. It was also observed that 228 (84.8%) practiced farming as their occupation while 41 (15.2%) did not; and 210 (78.1%) used fertilizers in farming, while 59 (21.9%) did not. Similarly, 24 (8.6%) students were enrolled in dental care, while 245

(91.1%) were not. Regarding the use of clay pots, 259 (96.3%) used clay pot for water storage or cooking, while 10 (43.7%) did not. This implies that most of the participants practiced farming as an occupation, used fertilizers in farming, and also used clay pots for water storage and cooking. Based on source of water, the table shows that the majority of the parents or guardians (52.8%) had borehole as their primary source of water.

As regards the characteristics of the parents whose children had fluorosis, it was observed that 97.4% of them were 21 to 50 years old, 87.1% lived together, and 89.2% ate family meals together. 50.6% of them had secondary education, 52.3% were unemployed, and 92.3% of them did not enroll their children in dental care program. Furthermore, 96% of them used clay pots for water storage while 55% used water from borehole sources. Again, 53% of them were from households with 6 to 10 family size.

The characteristics of parents whose children had fluorosis showed that the household size with the most children having fluorosis was 5 to 10(Appendix Q) and these accounted for 61.4% of the children fluorosis. The type of family composition, use of fertilizers in farms and storing water in clay pots did not significantly affect fluorosis in their children (fisher's $p = 0.1021$, Pearson's chi-square $p = 0.179$, fisher's $p= 1.000$ respectively; Appendix S, T and U). Similarly, the source of water used by the family did not significantly affect children's fluorosis (fisher's $p = 0.2214$, Appendix V). However, whether parents were employed or not significantly affected children fluorosis ($p = 0.050$, Appendix W).

Table 6
Parent or Guardian Characteristics

	Frequency	Percentage	Children with Yes	Fluorosis No
Gender				
Male	171	63.6	149	22
Female	98	36.4	84	14
Total	269	100	233	36
Age				
Less than 11years plus 11- 20 years	7	2.6	5	2
21 - 30 years	63	23.4	56	7
31 - 40 years	88	32.7	78	10
41 - 50 years	81	30.1	67	14
51 - 60 years	24	8.9	23	1
Above 60years	6	2.2	4	2
Total	269	100	233	36
Family composition				
Both parents together	230	85.5	203	27
Reconstituted parents	4	1.5	4	0
Single parent	30	11.2	23	7
No response	5	1.9	3	2
Total	269	100	233	36
Household size				
Below 6	63	23.4	50	9
6 - 10	148	55.0	123	19
11 – 15	30	11.2	25	4
16 – 20	12	4.5	12	0
21 – 25	7	2.6	6	2
26 – 30	3	1.1	3	0
Above 30	6	2.1	14	2
Total	269	100	233	36
Household religion				
Christianity	223	82.9	194	29
Moslem	45	16.7	39	6
Tradition	1	0.4	0	1
Total	269	100	233	36 *(table*

continues)

Eat family meals together				
Yes	239	82.9	208	31
No	30	16.7	25	5
Total	269	100	233	36
Household highest education				
Degree	59	21.9	54	4
Diploma/NCE	3	1.1	2	1
Secondary	138	51.3	118	20
Primary	32	11.9	26	6
No formal education	3	1.1	2	1
No response	34	12.6	31	3
Total	269	100	233	36
Employed				
Yes	123	45.7	111	12
No	146	54.3	122	24
Total	269	100	233	36
Practice farming as occupation				
Yes	228	84.8	197	31
No	41	15.2	36	5
Total	269	100	233	36
Use fertilizers in farming				
Yes	210	78.1	185	25
No	59	21.9	48	11
Total	269	100	233	36
Children enrolled in dental care program				
Yes	24	8.9	18	6
No	245	91.1	215	30
Total	269	100	233	36
Use a clay pot for water storage or cooking				
Yes	259	96.3	224	35
No	10	3.7	9	1
Total	269	100	233	36 *(table*

continues)

Source of water				
Borehole	142	52.8	128	14
Borehole and other sources	58	21.5	46	12
Public tap and other sources	21	7.8	18	3
Stream and other sources	48	17.9	41	7
Total	269	100	233	36
Children's method of maintaining oral hygiene				
Chewing stick				
Toothpaste	22	8.2	18	4
Others	241	89.6	211	30
Toothpaste and others	2	0.7	1	1
Chewing stick and others	1	0.37	0	1
Total	3	1.11	3	0
	269	100	233	36

Note: Age < 11 years was 0.4%, other water sources include well, river.

Community demographic characteristics. Table 7 shows the responses for the socio demographic characteristics of the community. The responses provided by the community leaders who were university graduates (50%) or had at least secondary education (72.2%) provided insight into the socio demographic characteristics of the community. As the table indicates, the most frequently used sources of water supply were boreholes and streams (77.8%). There was no dental care program in the Zing local government area, and the residents had no access to a dentist in the local government area. Additionally, water sources were not fluoridated in the community. The leaders also indicated that the most common health facilities used in the community were the primary health centers.

Table 7

Community Demographic Characteristics.

	Frequency	Percent
Qualification of community leaders.		
Graduates	9	50.0
Secondary/technical	4	22.2
Primary school	4	22.2
No school	1	5.6
Total	18	100
Water sources:		
Borehole	7	38.9
Stream	7	38.9
Stream, borehole, municipal	1	5.6
Stream, borehole	3	16.7
Total	18	100
Availability of dental program:		
No	14	77.8
Yes	4	22.2
Total	18	100
Access to dentist		
No	16	88.9
Yes	2	11.1
Total	18	100
Types of health facilities		
Hospitals	1	5.6
Primary care centers	15	83.3
Primary care centers,	2	11.1
hospitals	18	100
Total		
Fluoridation of water		
sources:	14	77.8
No	4	22.2
Yes	18	100
Total		

Representativeness of the Sample

The sample size for the study using a statistical power of 80% and an alpha level of .05 (95% CI) with an effect size of 0.3 for a small to medium effect (Cohen, 1998) was 176 (using a *t*-test for two independent samples). However, an additional 25% of 176 (i.e., the *t*-test value) was added to make up for attrition, bringing the sample size to 220. This sample size was for the students. To ensure, a representative sample, care was taken to enroll at a minimum 4 students from each class grade across the sampled schools in order to achieve the minimum sample of 192, since the *t*-test value was 176. When conducting the study, 281 participants were enrolled and administered questionnaires, out of which 269 participated, thereby bringing the total sample size used to 269. This implies that 12 of the enrolled participants were lost to attrition and this number represents 4.3%. Table 8 below present the representativeness of the sample and population using gender and age profiles of the sampled subjects and the population of interest (i.e., the number of children in the class registers of participating schools from where the sample was drawn).

Table 8

Representativeness of Sample to Population According to Age and Gender

Age group	Sample, male	Population, male	Sample, female	Population, female
5 -7	22	696	25	684
8 – 10	47	933	52	757
11 – 13	41	515	45	407
13 – 14	26	181	11	133
Total	136	2325	133	1981

Note: Representativeness in male (Fisher's p = <0.001, $X^2 = 32.593$, p = <0.001), female (Fisher's p = <0.001, $X^2 = 19.960$, p = <0.001). Cell by cell p value for male was p = 0.001, 0.197, 0.030, 0.000 for age groups 5 – 7, 8 - 10, 11 – 13, 14 - 15 respectively. Cell by cell p value for female was p = < 0.001, 0.839, <0.001, 0.490 respectively for age groups 5 – 7, 8 - 10, 11 – 13, 14 – 15 respectively. *Winpepi* statistical tool used for test of significance.

From Table 8, it can be seen that the null hypothesis (H_o) that there is no significant difference between the sample and the population for both age and gender is not supported. The fisher's and Pearson chi-square *p* value for age in both genders is $p < 0.001$ indicating that the sample significantly differed from the population for both gender and age. This difference was more in age groups 5 to 7, 11 to 13, 14 to 15 in the males, and age group 5 to 7, 11 to 13 in the females ($p = 0.001$, 0.030, <0.001, <0.001, <0.001, respectively). However, there was no statistically significant difference in the age groups 8 to 10 years old in the male, and the 8 to 10years, 14 to 15 years in the female ($p = 0.197$, 0.839, 0.490, respectively). However, as noted above, the representativeness of the sample was not achieved despite all attempts at systematic random sampling.

Table 9, presents the proportion of sample distributed across the class grades and according to gender. It shows a progressive increase in the proportion of participants in favor of the higher grades when compared with the population. This progressive increase was 2.6% for grade 1, 4.7% for grade 2, 7.1% for grade 3, 7.7% for grade 4, 4.9% for grade 5 and, 15.5% for grade 6 thereby skewing the sample distribution towards the higher grades. This skew may have resulted from the loss of participants to attrition after sampling and also the subsequent dropping of some enrolled students during the data sorting stage for not meeting the inclusion criteria, which affected more of the lower classes as noted in table 5. The proportional representation of the sample across the grades especially the lower classes was affected as it was easier for the parents of the children in the lower classes to discontinue participation due to lack of understanding, since many of these pupils were there only for the school meals. The recently introduced policy of the State government to encourage schooling through the free meal program in schools affected the enrollment of pupils into the educational program especially into the lower classes. This affected the proportional representation of the sample, as many children come to school mainly for the free meals and not really as enrolled pupils. This is easy to understand when you look at the poor SES of the community. Thus, these loses may undermined the proportion of the sample across the class grades. In the two instances, the grade 1 was negatively impacted as many more pupils were in the class register than actually available in school and grade 6 was positively impacted as these pupils were older and full students. Generally, this bias in the representativeness of the sample to the population may affect the generalization of the study findings to other areas as regards the goal of the study.

Table 9.

Gender Profile of Sample and Population According to Class grade.

Class grade	Children in class register	Population: Male	Population: Female	Sample: Male	Sample: Female	Proportion of sample : population
1	1,095	577	518	10	19	2.6
2	787	456	331	21	16	4.7
3	704	368	336	26	24	7.1
4	634	328	296	20	28	7.7
5	611	330	281	13	17	4.9
6	485	310	175	46	29	15.5
Total	4,306	2,369	1,937	136	133	

Descriptive Analysis

Table 10 presents the descriptive results of the variables used in the regression analysis (from Survey 1 and the checklist for field investigation of fluorosis). The average value of the level of the severity of fluorosis (Sfl) was 3.40 with a SD (Standard deviation) of 2.00. Fluoride content in water (Fcwmgl) had a minimum value of 1.00

mg/l and a maximum value of 6.80 mg/l, with an average value of 3.47 mg/l and an SD of 1.96mg/l (Figure 11). The fluoride content in the soil (Fcsmgl) had an average value of 0.39 mg/l with an SD of 0.96 mg/l (Figure 12). The estimated average value of fluoride content in food, including dawa, and bambara (Fcvmgl), was 6.49mg/l with an SD of 0.89 mg/l (Figure 13). The minimum and maximum values were 5.75 mg/l and 8.20 mg/l, respectively.

Table 10.

Descriptive Results of Fluoride in Water, Soil, and Food, and the Severity of Fluorosis.

	N	Min	Max	Mean	SD
Severity of fluorosis	269	0.00	6.00	3.40	2.00
Fluoride content in water	269	1.00	6.80	3.47	1.96
Fluoride content in soil	269	0.00	3.00	0.39	0.96
Fluoride content in food	269	5.75	8.20	6.49	0.89

Table 11

Descriptive Results of Fluoride in Dawa and Bambara Sampled in the Zing Community

	N	Min	Max	Mean	SD
Fluoride content in dawa	242	6.5	8.4	7.194	.733
Fluoride content in bambara	275	5.6	8.2	6.606	1.151

Table 11 presents the mean fluoride content in dawa and bambara sampled in the study area. The table shows that the mean fluoride content in both dawa and bambara are high (above 1 mg/l).

Figures 11, 12, 13 presents scatter plots of the fluoride content in the water, soil, and vegetables, as well as the TSIF score of fluorosis.

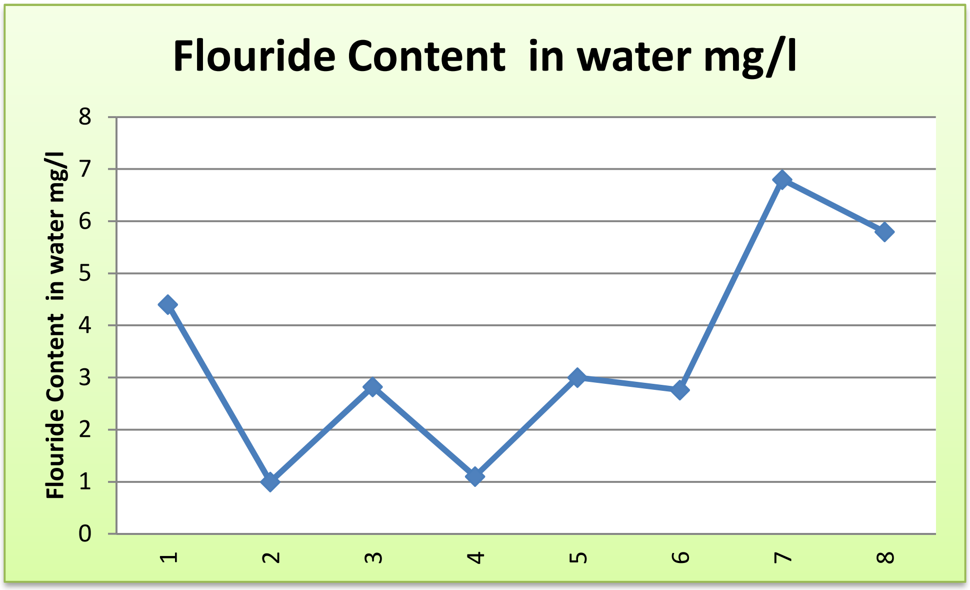

Figure 11. Scatter Plot of Fluoride Content in Water.

Figure 11, shows the high level of fluoride (above 1mg/l) in more than 70% of the water sources sampled.

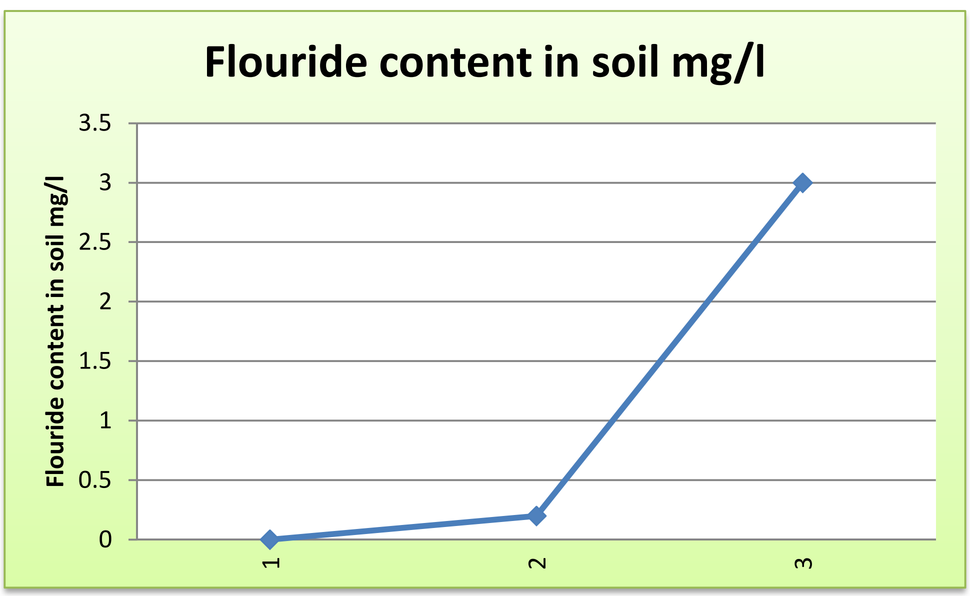

Figure 12. Scatter Plot of Fluoride Content in Soil.

The figure shows the high fluoride content (above 1 mg/l) in one of the three sources sampled.

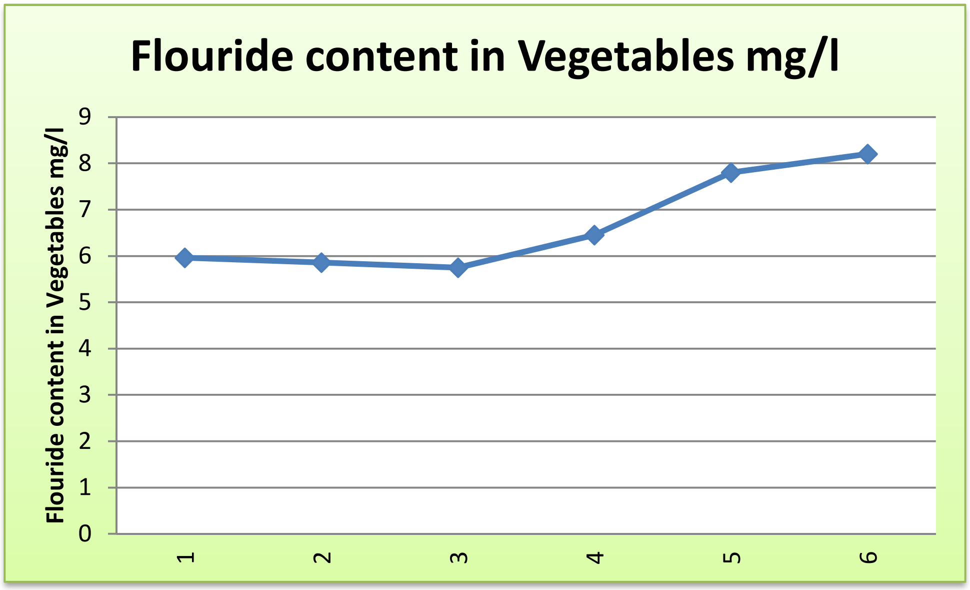

Figure 13. Scatter Plot of Fluoride Content in Vegetables.

The figure shows the consistently high fluoride levels in vegetables from all sources sampled.

Correlation Analysis

Table 12 reports the results of the preliminary correlation analyses among the variables. Generally, the result shows that Fcsmgl and Fcvmgl are positively correlated with Sfl, while Fcwmgl is negatively correlated with Sfl. Specifically, the correlation between Fcsmgl and Sfl is found to be statistically significant at 1%. This implies that, fluoride content in the soil is significantly correlated with the level of severity of fluorosis.

Table 12.

Correlation Results

	Severity of fluorosis (Sfi)	Fluoride content water(Fcwmgl)	Fluoride content soil (Fcsmgl)	Fluoride content food(Fcvmgl)
Severity of fluorosis (Sfi)	1			
Fluoride content water (Fcwmgl)	-0.072	1		
Fluoride content soil (Fcsmgl)	0.251**	0.431**	1	
Fluoride content food (Fcvmgl)	-0.134*	-0.016	-0.067	1

Note:*.Correlation is significant at the 0.05 level (2-tailed). **. Correlation is significant at the 0.01 level (2-tailed).

Inferential Statistics

Chi Square Results

Hypothesis 2

H_0: There is no association between the presence of fluorosis among children and dawa consumption.

H_1: There is an association between the presence of fluorosis among children and dawa consumption.

Table 13 depicts the result of association (from Survey 1) between dental fluorosis and the consumption of dawa among children in the Zing community. The results show that “0 cells (0.0%) had an expected count of less than 5, and the minimum expected count was 5.49.” This implies that the sample size requirement for the chi-square test of independence is satisfied. The Pearson chi-square statistic ($X^2 = 0.568$ and $p > 0.10$) of the observed data under the null hypothesis of no relationship suggests the acceptance of the null hypothesis and concludes that there is no significant association between dawa consumption and the presence of fluorosis among children in the Zing community. This means that the difference between the observed and expected values is due to chance. Furthermore, the data show that, of the 228 children who stated that they eat dawa 199 had fluorosis (87.28%) while 34 of the 41 children who did not eat dawa had fluorosis (82.92%).

Table 13

A 2x2 Contingency Chi-Square Test of the Association Between Dawa Consumption and the Presence of Fluorosis.

Diagnosis of Fluorosis	Consumption of Dawa			df	X2	Sig.
	No	Yes	Total			
Yes	34(35.5)	199(197.5)	233(233)			
No	7(5.5)	29(30.5)	36(36)	1	0.568	0.451
Total	41(41)	228(228)	269(269)			

* The minimum expected count (in parenthesis) was 5.49. Chi-square requirements satisfied. Person chi-square statistic is not significant at 95% C.I.

Hypothesis 3

H_0: There is no association between the presence of fluorosis among children in the Zing community and bambara consumption.

H_1: There is an association between the presence of fluorosis among children in the Zing community and bambara consumption.

Table 14 presents the chi-square test result of the association (Survey 1) between the presence of fluorosis in children and bambara consumption. The result shows that "1 cell (25.0%) had an expected count of less than 5, and the minimum expected count was 2.28." This implies that the sample size requirement for chi-square test of independence is not satisfied. Hence, Fisher's exact test is used. Fisher's exact test two-side significance value (*p*=0.06) suggests a rejection of the research hypothesis. This means that there is no significant association between bambara consumption and the presence of fluorosis in children in the Zing community. However, based on these results, 87.70% of the children who ate bambara (221 out of 252 children) had fluorosis while, 70.59% of those that did not eat bambara had fluorosis (12 out of 17 children).

Table 14

A 2x2 Contingency Chi-Square Test of the Association Between Bambara Consumption and the Presence of Fluorosis.

Diagnosis of	Consumption of Bambara			Sig
Fluorosis	No	Yes	Total	
Yes	12(14.7)	221(218.3)	233(233)	
No	5(2.3)	31(33.7)	36(36)	0.06
Total	17(17)	252(252)	269(269)	

*1 cell (25.0%) had an expected count (in parenthesis) of less than 5. The minimum expected count was 2.28. Chi-square conditions not met. Fisher's *p* value used. *P* = 0.06 not significant at 95% C.I.

Hypothesis 4

H_0: There is no association between the presence of fluorosis among children in the Zing community and the use of clay pots by households.

H_1: There is an association between the presence of fluorosis among children in the Zing community and the use of clay pots by households.

Table 15 depicts the association (Survey 2) between dental fluorosis among children and the use of clay pot for water storage or cooking in the Zing community. The table shows that the chi-square assumption was violated as "1 cell (25.0%) had an expected count of less than 5, and the minimum expected count was 1.34." The two-sided exact significance of the Fisher's exact test (*p*=1.000) was greater than 0.10, showing that there is no significant association between the use of clay pots and dental fluorosis in children in the Zing community. However, the result shows that the percentage of those who used clay pots for water storage or cooking (224 out of 259 children) and had fluorosis is 86.48% while, those who did not use clay pots for water storage or cooking and had fluorosis (9 out of 10 children) is 90.0%.

Table 15

A 2x2 Contingency Chi-Square Test of the Association Between the Use of Clay Pots for Water Storage or Cooking and the Presence of Fluorosis.

Diagnosis of	Use of clay pots for water storage/cooking			Sig
Fluorosis	Yes	No	Total	
Yes	224(224.3)	9(8.7)	233(233)	1.000
No	35(34.7)	1(1.3)	36(36)	
Total	259(259)	10(10)	269(269)	

*1 cell (25.0%) had an expected count (in parenthesis) of less than 5. The minimum expected count was 1.34. Chi-square conditions not met. Fisher's test used.

Hypothesis 5

H_0: There is no association between the presence of fluorosis among children in the Zing community and cropping on hilly sites.

H_1: There is an association between the presence of fluorosis among children in the Zing community and cropping on hilly sites.

Table 16 presents the association (Survey 2) between the farm location and the presence of fluorosis among the children in the Zing Community. The results show that "1 cell (12.5%) had an expected count of less than 5 and the minimum expected was 2.28," which implies that the sample size requirement for chi-square test of independence is satisfied. The probability of the chi-square test statistic (chi-square =4.62, *p*=0.202) was greater than alpha level of significance of 0.10, which implies that there is no association between the presence of fluorosis among children and farm location.

Of the 39 children who helped to cultivate land in the valley, 30 had fluorosis (76.9%); of the 169 children who helped to cultivate land in a low area, 147 had fluorosis (86.9%) and of the 22 who help to cultivate land on hilly site, 20 had fluorosis (90.9%).

Table 16

A 2x2 Contingency Chi-Square Test of the Association Between Farm Location and the Presence of Fluorosis.

Diagnosis of fluorosis		Farm	location					
	Valley	Low land	Hilly site	None	Total	Df	X2	Sig.
Yes	30(33.8)	147(146.4)	20(19.1)	36(33.8)	233(233)			
No	9(5.2)	22(22.6)	2(2.9)	3(5.2)	36(36)	3	4.62	0.202
Total	39(39)	169(169)	22(22)	39(39)	269(269)			

*1 cell (12.5%) had an expected count (in parenthesis) of less than 5. The minimum expected count was 2.94. Chi-square conditions met. *P* > 0.05, not significant.

Hypothesis 6

H_0: There is no association between the use of fertilizers in farming and a diagnosis of fluorosis in children.

H_1: There is an association between the use of fertilizers in farming and a diagnosis of fluorosis in children.

Table 17 presents the results of the test of the relationship (Survey 2) between the use of fertilizers in farming and dental fluorosis among children. The result shows that "0 cells (0.0%) had an expected count of less than 5, and the minimum expected count was 7.90." This implies that the sample size requirement for chi-square test of independence was satisfied. The probability of the chi-square test statistic ($X^2 = 3.155$ and p=0.076) is more than the alpha level of significance of 0.05. Thus, the null hypothesis that there is no association between the use of fertilizers in farming and the diagnosis of fluorosis in children is supported. Hence, there is no significant association between the use of fertilizers in farming and fluorosis among children in the Zing community. Furthermore, of the 210 participants who used fertilizers in farming, 186 had fluorosis (88.6%) while of the 59 participants who did not use fertilizers in farming, 47 had fluorosis (79.7%).

Table 17

A 2x2 Contingency Chi-Square Test of the Association Between the Use of Fertilizers in Farming and the Presence of Fluorosis.

Diagnosis of	The Use of Fertilizer in farming			df	X_2	
Fluorosis	Yes	No	Total			Sig.
Yes	156(181.9)	47(51.1)	233(233)			
No	22(28.1)	12(7.9)	36(36)	1	3.155	0.076
Total	210(210)	59(59)	269(269)			

* The minimum expected count (in parenthesis) was 7.90. Chi-square conditions met. $P > 0.05$, not significant at 95% CI.

Hypothesis 8

H_0: There is no association between family SES and fluorosis in children.

H_1: There is an association between family SES and fluorosis in children.

Table 18 presents the chi-square test's result of the association (Survey 1) between the SES and a diagnosis of fluorosis in the children. These results show that, "2 cells (33.3%) had expected count less than 5, and the minimum expected count was 0.40." Consequently, the chi-square test of independence is not satisfied, and the Fisher's exact result is used. These results show that the two-sided exact significance is 0.027. Since the significance value is less than 0.05, the null hypothesis is rejected and shows that there is a significant association between family SES and fluorosis among children in the Zing community. This was more significant in the lower and middle SES (P = 0.009 and 0.014) than in the high SES (P = 0.494).

Table 18

A 2x3 Contingency Chi-Square Test of the Association Between Family SES and the Presence of Fluorosis.

Diagnosis	Family SES				
of Fluorosis	Low	Middle	High	Total	Sig.
Yes	175(181)	55(49.4)	3(2.6)	233(233)	
No	34(28)	2(7.6)	0(0.4)	36(36)	0.027
Total	209(209)	57(57)	3(3)	269(269)	

*2 cells (33.3%) had expected count (in parenthesis) of less than 5. The minimum expected count was 0.40. Chi-square conditions not met. Fisher's exact test used, p = 0.027 significant at 95% C.I. Cell by cell analyses p = 0.009, 0.014(low and middle SES) and p = 0.494(high SES).

Regression Results

Hypothesis 7

H_0: There is no relationship between the severity of fluorosis and the level of fluoride in the water, food and soil.

H_1: There is a relationship between the severity of fluorosis and the level of fluoride in the water, food, and soil.

The regression results of the relationship between the fluoride content in the water, soil, and food and the level of severity of fluorosis (Survey 1 and checklist) are presented in Table 18. In the table, the R^2 (co-efficient of determination) indicates that about 11.6% of the variation in Sfl is explained by the dependent variables. The adjusted R^2 shows that even if all the missing variables are included in the model, 10.6% of the variations in Sfl will still be explained by the explanatory variables. The F-statistic is highly significant at a 1% level of significance. These confirm a high predictive ability and usefulness of the model.

In general, the results show that fluoride content in water had negative relationship with the level of fluorosis (Sfi) while fluoride content in soil had positive relationship with the level of fluorosis (Sfi). However, the relationships are significantly associated with the level of severity of fluorosis (Sfl) at 5% and 1% levels, respectively. This implies that fluoride content in the water and soil is a major determinant of the level of severity of fluorosis in the community. However, contrary to expectation, fluorosis in this study correlates well with less fluoride in the water but as expected, it correlates with more fluoride in the soil.

In order to avoid wrong inferences in the regression analysis, the variables of age (continuous), and class grade of child (ordinal) were not included in the regression analysis model, since the fluoride content estimated in water and soil were determined from sources in the primary school and other public locations which may not be the same sources used by the households. Therefore the predictive model is given generally as it relates to these variables in the community and to RQ 7.

Thus, the predictive model is given as:

$$Sfl = 5.569 - 0.224(Fcwmgl) + 0.703(Fcsmgl) - 0.258(Fcvmgl) + \varepsilon. \quad (3)$$

Table 19

Regression Result

Variable	Coefficient
Constant	5.569(0.879)***
Fluoride content in Water measured in mg/l	-0.224(0.065)***
Fluoride content in Soil measured in mg/l	0.703(0.134)***
Fluoride content in Food measured in mg/l	-0.258(0.130)
Model Criteria	
R-squared	0.116
Adjusted R-squared	0.106
F-statistic	11.580
Prob(F-statistic)	0.000

Note: *, **, and *** represent significance levels of 10%, 5%, and 1%, respectively. The standard error is in the parentheses. The dependent variable is the level of severity of fluorosis.

Regression Model Specification

The model is specified in a functional form to capture the relationship between fluoride content in water, soil and food and the level of severity of fluorosis.

$$Sfl = f(Fcwmgl, Fcsmgl, Fcvmgl), \quad (1)$$

where

Sfl is the level of severity of fluorosis,

Fcwmgl is the fluoride content in the water measured in mg/l,

Fcsmgl is the fluoride content in the soil measured in mg/l, *and*

Fcvmgl is the fluoride content in the food measured in mg/l.

Thus, the OLS estimation is given as

$$Sfl = \beta_0 + \beta_1 Fcwmgl + \beta_2 Fcsmgl + \beta_3 Fcvmgl + \varepsilon, \quad (2)$$

where β_0 is constant; β_1, β_2 *and* β_3 are the coefficients of the dependent variables; and ε is the error term.

Justification of the Data Analysis Method

Chi-square statistic. The chi-square statistic is a non-parametric (distribution free) tool designed to analyze group differences when the dependent variable is measured at a nominal level (i.e., categorical data). Accordingly, it does not require equality of variances among the study groups or homoscedasticity in the data. It allows evaluation of both dichotomous independent variables, and of multiple group studies. Its robustness with respect to distribution of the data and the detailed information that can be derived from the test necessitated its use for this study.

Assumptions. There are three major assumptions: (a) the two variables should be measured at an ordinal or nominal level (i.e., categorical data), and (b) the variables should consist of two or more categorical, independent groups.

It should be noted that descriptive statistics, such as mean, standard deviation, range, and so on, can only be used for continuous variables. That is, they are not compatible with categorical variables. Frequency, percentage, charts, and crosstabs can be used for categorical variables. In this study, the assumption is that the severity of fluorosis is influenced generally by the level of fluoride in water, soil and foods found in the community.

Further Exploratory Investigations of the Results Using Influences of Children's Oral Health.

Further exploratory investigations focused on 12 influences on children's oral health using the Fisher-Owens et al. (2007) model. Some significant influences that could be linked with dental fluorosis were found in the study sample. These were at the child, parent and community levels.

Child Level

At the child level, some of the influences were the number of years the children had lived in the area, and their age. Furthermore, their health behaviors and knowledge of illness, as well as their SES also influenced dental fluorosis. However, the gender of the child did not significantly influence the severity of fluorosis in the children.

Table 20

2x2 Contingency Table Between Diagnosis of Fluorosis and Years Lived in the Area

	Years Stayed							
Diagnosis of fluorosis	5-7 years	8-10 years	11-13 years	14-15 years	Total	df	X2	Sig.
Yes	42(41.6)	89(88.3)	77(72.8)	25(30.3)	233(233)			
No	6(6.4)	13(13.7)	7(11.2)	10(4.7)	36(36)	3	8.881	0.031
Total	48(48)	102(102)	84(84)	35(35)	269(269)			

*1 cell (12.5%) had expected count (in parenthesis) of less than 5. The minimum expected was 4.68. Chi-square conditions met. *P* = 0.031; 0.005(14 - 15 age group). Significant at 95% CI.

The results show that “1 cell (12.5%) had an expected count of less than 5, and the minimum expected was 4.68,” which implies that the sample size requirement for the chi-square test of independence is satisfied. The probability of the chi-square test statistic (X^2 = 8.881, *p*=0.031) was less than the alpha level of significance of 0.05 and implies that the length of time the child had lived in the area significantly influenced a diagnosis of fluorosis. This was similarly affected by the age of the child since the children had lived in the area since birth. Table 21 below shows the results from further testing of the presence of fluorosis and gender.

Table 21

A 2x2 Contingency Chi-Square Test of the Presence of Fluorosis and Gender.

	Gender					
Diagnosis of Fluorosis	Male	Female	Total	df	X2	Sig
Yes	120(117.8)	113(115.2)	233(233)			
No	16(18.2)	20(17.8)	36(36)	1	0.621	0.431
Total	136(136)	133(133)	269(269)			

* The minimum expected count (in parenthesis) was 17.80. Chi-square conditions met. Not significant at alpha level 0.05.

Table 21 shows a 2 x 2 contingency table of gender and the diagnosis of fluorosis. The result shows that “0 cell (0.0%) had expected count of less than 5, and the minimum expected was 17.80” which implies that the sample size requirement for the chi-square test of independence was satisfied. The probability of the chi-square test statistic (X^2 = 0.621, *p*=0.431) was more than the alpha level of significance of 0.05 and implies that there is no statistical difference between gender and the development of fluorosis.

Table 22

A 2 x 2 Contingency Chi-Square Test of the Severity of Fluorosis and Gender.

	Gender					
Severity of Flourosis	Male	Female	Total	df	X2	Sig
Mild	48(41)	33(40)	81(81)			
Normal	17(17.2)	17(16.8)	34(34)			
Moderate	35(41)	46(40)	81(81)	3	4.252	0.235
Severe	36(36.9)	37(36.1)	73(73)			
Total	136(136)	133(133)	269(269)			

* The minimum expected count (in parenthesis) was 16.81.Chi-square conditions met. Not significant at alpha level of 0.05.

In Table 22, the results of the 2x2 contingency test are presented. They show that "0 cells (0.0%) had an expected count of less than 5, and the minimum expected was 16.81," which implies that the sample size requirement for chi-square test of independence was satisfied. The probability of the chi-square test statistic ($X^2 = 4.252$, p=0.235) was more than the alpha level of significance of 0.05 and implies that there is no statistical difference between the sexes on the severity of fluorosis.

Table 23
A 2x2 Contingency Table Between Diagnosis of Fluorosis and Family SES

Diagnosis	Family SES				
of Fluorosis	Low	Middle	High	Total	Sig.
Yes	175(181)	55(49.4)	3(2.6)	233(233)	
No	34(28)	2(7.6)	0(0.4)	36(36)	0.027
Total	209(209)	57(57)	3(3)	269(269)	

*2 cells (33.3%) had expected count (in parenthesis) of less than 5. The minimum expected count was 0.40. Chi-sqaure conditions were not met. Fisher test used.

The results in Table 23 show that, “2 cells (33.3%) had an expected count of less than 5, and the minimum expected count was 0.40,” consequently, the chi-square test of independence was not satisfied, and the Fisher’s exact result was used. These results show that the two-sided exact significance was 0.027. Since the significance value was less than 0.05, the null hypothesis is rejected, and there is a significant association between family SES and fluorosis among children in the Zing community. This shows that SES significantly influenced the diagnosis of fluorosis among children.

Regarding the children’s attitude to health (judged by the appearance of their teeth), the results in Table 24 show that “0 cells (0.0%) had an expected count of less than 5, and the minimum expected count was 15.26.” This implies that the sample size requirement for the chi-square test of independence was satisfied. The Pearson chi-square statistic ($X^2 = 18.112$ and $p = <0.001$) of the observed data suggest a significant association between the influence of a child’s attitude to health and the presence of fluorosis. This shows that their attitude regarding the appearance of their teeth significantly influenced the diagnosis of fluorosis among the children. Hence, there was a significant association between attitude regarding the appearance of their teeth and the presence of fluorosis among the children in the Zing community.

Table 24

2 x 2 Contingency Table Between Presence of Fluorosis and the Child's Attitude to Health (Appearance of Teeth)

Diagnosis of Fluorosis	Like appearance of teeth Yes	No	Total	df	X^2	*P*-value
Yes	87(98.7)	143(134.3)	233(233)			
No	27(15.3)	9(20.7)	36(36)	1	18.112	<0.001
Total	114(114)	155(155)	269			

* The minimum expected count (in parenthesis) was 15.26. Chi-square conditions are met. Significant at 95% CI.

Regarding how the children described the color of their teeth (Table 25), the results show that "0 cells (0.0%) had an expected count of less than 5, and the minimum expected count was 11.11." This implies that the sample size requirement for the chi-square test of independence was satisfied. The Pearson chi-square statistic ($X^2 = 21.258$ and $p = <0.001$) of the observed data suggests that there is a significant association between the children's knowledge of the illness and their attitude and the presence of fluorosis. Hence, there was significant association between awareness of the color of their teeth and the presence of fluorosis among children in the Zing community.

Table 25

2x2 Contingency Table Between the Presence of Fluorosis and Child's Knowledge of Illness (Can Describe Color of Their Teeth)

	Noticed color change on teeth					
Diagnosis of fluorosis	Yes	No	Total	df	X2	Sig.
Yes	173(161.1)	60(71.9)	233(233)			
No	13(24.9)	23(11.1)	36(36)	1	21.258	<0.001
Total	186(186)	83(83)	269(269)			

* The minimum expected count (in parenthesis) was 11.11. Chi-square conditions are met. Significant at 95% CI.

Parent Level Influences

The exploratory tests of family composition, household size, household highest education, and enrollment in a dental care program were not significant in relation to the children having dental fluorosis. The *p* values for these variables were 0.1021, 0.516, 0.994, and 0.109, respectively (Appendix S, X, Y and Table 26). There was no significant association between how parents maintained their children's oral hygiene. Here, the two-sided Fisher exact value was $p = 0.083$. However, there was a significant association between parent's employment status and fluorosis in their children ($p = 0.050$, Appendix W).

Regarding the presence of fluorosis and enrollment in a dental care program (Table 26), the results show that "1 cell (25.0%) had an expected count of less than 5, and the minimum expected count was 3.21." Consequently, the chi-square test of independence is not satisfied, and the Fisher's exact result was therefore used. The results show that the two-sided exact significance of Fisher's test was 0.109. Since the significance value was more than 0.05, the study concludes that there is no significant association between the enrollment of children in dental care programs and fluorosis among children in the Zing community.

Table 26

2 x 2 Contingency Table Between Presence of Fluorosis and Enrollment in Dental Care Program

	Children enrolled in dental care program			
Diagnosis of fluorosis	Yes	No	Total	Sig.
Yes	18(20.8)	215(212.2)	233(233)	
No	6(3.2)	30(32.8)	36(36)	0.109
Total	24(24)	245(245)	269(269)	

* 1 cell (25.0%) had expected count (in parenthesis) of less than 5. The minimum expected count was 3.21. Chi-square conditions not met. Fisher's test used. Not significant at 95% CI.

Regarding the presence of fluorosis and the children's chosen method for maintaining oral hygiene (Table 27), these results show that "7 cells (70.0%) had an expected count of less than 5, and the minimum expected count was 0.13." Consequently, the chi-square test of independence was not satisfied, and the Fisher's exact result was used, which showed that the two-sided exact significance was 0.083. Since the significance value was more than 0.05, the study concluded that there is no significant association between the way that the children cared for their teeth and the prevalence of fluorosis among children in the Zing community.

Table 27

2 x 2 Contingency Table Between the Presence of Fluorosis and Chosen Method for Maintaining Oral Hygiene.

	Tooth paste, Chewing stick, Other						Sig.
Diagnosis of fluorosis	Chewing stick	Toothpaste	Other	Toothpaste and other	Chewing stick and other	Total	
Yes	18(19.1)	211(208.7)	1(1.7)	0(0.9)	3(2.6)	233(233)	0.083
No	4(2.9)	30(32.3)	1(0.3)	1(0.1)	0(0.4)	36(36)	
Total	22(22)	241(241)	2(2)	1(1)	3(3)	269(269)	

* 7 cells (70.0%) had expected count (in parenthesis) of less than 5. The minimum expected count was 0.13. Conditions for use of chi-square test statistic were not met, hence fisher test was used. Not significant at 95%CI.

Community level Influences.

Although not tested for significance, the community-level influences highlighted in the demographic characteristics revealed the following: (a) there is no dental care program provided by the local government, (b) there is no access to a dentist in the community, (c) water sources are not fluoridated, and (d) the most frequently used sources of water in the community are the boreholes and streams (77.8%).

Study Findings

This study involved a field survey of children participants aged 5 to 15 years, as well as their parents/guardians and community leaders. The sample used for the study was 556 participants including 269 children (Survey 1), 269 parents (Survey 2) and 18 community leaders (Survey 3). The surveys were designed to determine possible influences on children's oral health at the child, parent/household, and the community levels.

The child participants were comprised of approximately 30 pupils from each of the 8 participating schools involved in the study and were drawn from all six grades of these primary schools. The socio demographic characteristics of the population included the following; the children were all between 5 to 15 years of age, with 68.7% of them between the ages of 8 to 13 years. 50.6% of the children were male, while 49.4% were female and the gender ratios across the various age groups were comparable. An Independent sample *t* - test shows that the mean age of children in the study was male (10.63 ± SD 2.86), and female (9.88 ± SD 2.60). This was significant at a *p* value of 0.025 (Appendix I) and indicates that the male students were slightly older than the female students.

The grades of the children involved in the study ranged from Grade 1 to Grade 6. The gender ratios across the grades were comparable , a Pearson chi-square test of these class gender characteristics were not statistically significant at *p* value of 0.10 (Appendix J) indicating that there was no significant difference between gender distributions across the grades. 77.7% of the children were from low-SES families (Table 5), and 68.7% of the children had lived in the study area for 8 to13 years (Table 5).

71% of the children involved in the study preferred to seek medical treatment at a clinic (Table 5). This students characteristic was comparable across genders (p = 0.683, Appendix K). Furthermore, a great majority of the children used toothpaste on a brush to clean their teeth, and this characteristic differed significantly between the gender (p = 0.0239) with more female using toothpaste on brush than male (Appendix L). However, there was no significant difference between the gender on being taught oral hygiene in school (*p* = 0.517, Appendix M). There was also, no significant difference between the gender on who eats breakfast, lunch and dinner daily (p = 0.817, Appendix N).

The age structure of their parents and guardians ranged from 11 to 75 years, with majority of them between the ages of 21 to50 years (86.2%, Table 6). 76.2% of the parents lived together (Table 6), and on household size, 55% had a family size of 6 to10 people (Table 6). 89% of the households ate family meals together (Table 6). Furthermore, 54% of the parents were unemployed (Table 6), and the highest education in about 51.3% of the households was secondary education (Table 6), while, 96.3% of households used clay pots for storing water or cooking (Table 6).

The demographic characteristics of the community include the following: the most frequent sources of water used in the community were boreholes and streams (77.8%, Table 7). 77.8% of the people had no access to a dental care program in the local government area (Table 7), while 88.9% of them had no access to a dentist (Table 7). 77.8% of water sources were not fluoridated (Table 7), and the most available health facilities in the community were primary health centers (Table 7).

The results of the study show the following: the age range of the sample was 5 to 15 years, and 50.6% of them were male and 49.4% were female. The length of time that the majority of the children (68.7%) had lived in the study area was 8 to 13 years (Table 5). 84.4% of the children ate dawa (Table 5), while 93.7% of them ate bambara (Table 5). 78.1% of the parents used fertilizers on their farms, and 21.9% did not (Table 6). Furthermore, 96.3 % of households used clay pots for storing water, while 3.7% did not

(Table 6). 8.2% of parents farmed on hilly sites, 62.8% farmed on level ground, 11.2% farmed in a valley, and 14.5 % were unclassified (Table16).

On parents whose children had fluorosis, 97.4% of them were between 21 to 50 years old, 87.1% of them lived together as parents, and 89.2% of them ate family meals together. 50.6% of them had secondary education, 52.3% were unemployed, and 92.3% of them did not enroll their children in dental care program. Furthermore, 96% of them used clay pots for storing water, 55% used water from boreholes, while 53% of them had household size of between 6 to 10 persons (Table 6).

The type of family composition, use of fertilizers, storing water in clay pots and source of water used by the family did not significantly affect children fluorosis (p = 0.1021, 0.179, 1.000, 0.2214; Appendix S, T, U and V). However, parent's employment status significantly affected diagnosis of fluorosis in children ($p = 0.050$, Appendix W).

The percentage of children in the study diagnosed with fluorosis was 86.6%, indicating a high prevalence rate (Figure 8). Those without fluorosis accounted for 13.6%. The prevalence of fluorosis according to gender was 88.2% for males, and 85.0% for females (Figure 9). There was no significant difference between the gender in the diagnosis of fluorosis ($p = 0.432$, Appendix P). The age group with the highest prevalence of fluorosis was 8 to10 years (37.3%), followed by 11 to13 years (33.5%). Thus, 70.8% of children with fluorosis were between the ages of 8 to 13years (Figure 10).

The mean age of children with fluorosis was 10.20 ± SD 2.68, and those without fluorosis was10.80 ± SD 3.22. This was not statistically significant at p value of 0.181 (Appendix O), indicating that there was no significant difference in the age of children with fluorosis and those without fluorosis. The difference between the children with fluorosis and those without fluorosis was accounted for by the length of stay in the community, the age of the student, family SES, student's attitude to health and the student's knowledge of illness, *p* value 0.031, 0.027, <0.001 and <0.001 respectively (Tables 20, 23, 24 and 25).

On test of hypotheses, the association of the presence of fluorosis with dawa consumption in Research Question 2 was not significant. The test of significance for the association with dawa was $X^2 = 0.568$, $p = 0.451$ (Table 13). The test of association between the presence of fluorosis and bambara consumption in Research Question 3 was also not significant, with the Fisher's exact test two-sided significance value of $p = 0.06$ (Table 14). Furthermore, the test of association of the presence of fluorosis with the use of clay pots for storing water and cropping on hilly sites in Research Questions 4 and 5 were not significant. The Fisher's exact value for the use of clay pots was 1.000 and the chi-square value for cropping on hilly sites was $X^2 = 4.62$, $p = 0.202$ (Tables 15 and 16).

The test of significance in association with the use of fertilizers in farming and fluorosis in children in Research Question 6 was not significant with a Fisher's exact value of 0.076 indicating no association between fluorosis, and the use of fertilizers (Table 17). However, in testing for the influence of family SES on the prevalence of fluorosis in the study in Research Question 8, the Fisher's *p* value of 0.027 was significant indicating that family SES significantly influenced the presence of fluorosis in children, and this was more associated with low and middle SES

Although not related to the test of association, the levels of fluoride in dawa (mean value: 7.2mg/l) and, bambara (mean value: 6.6mg/l) were above the recommended WHO level of 1.0 mg/l (Table 11). The mean fluoride content in the water sources, food, and soil in the study area was 3.47mg/l, 6.49mg/l, and 0.39mg/l, respectively (Table 10, Figures 11, 12, 13). The values for the water and food are both above the WHO allowable level of 1.0 mg/l.

The mean score of the severity of fluorosis using the TSIF scale was 3.4 (Table 10), which is classified as moderate on the scale. Generally, the correlation result shows that Fcsmgl and Fcvmgl are positively correlated with Sfi while Fcwmgl is negatively correlated with Sfi (Table 12). In addition to these findings, the severity of fluorosis was significantly associated with the level of fluoride content in the water, soil, and food. The regression analysis model showed that an explained variance of 11.6% in the severity of fluorosis was accounted for by the explanatory variables of fluoride in the water, soil and food.

The F test showed a significant predictive association between fluorosis and the three factors, with an F value of 11.580 ($p = < 0.001$). Furthermore, the analysis showed that the predictive weight of fluoride in soil was significant at $t = 5.569$ ($p = < 0.001$). The predictive equation for the association is Sfi = 5.569 - 0.224(fcwmgl) + 0.703(fcsmgl) - 0.258(fcvmgl). In general, the fluoride content in the water and soil was significantly associated with the level of severity of fluorosis in the children (SfI), at 10% and 1% levels of significance, respectively.

Further exploratory findings in the study showed a statistical significant association between the development of fluorosis with age and length of stay of student in the area (X^2 8.881, $p = 0.031$) in favor of higher age and length of stay, family SES (Fisher's $p = 0.027$) in favor of low and mid SES, children's attitude to health ($X^2 = 18.112$, $p = < 0.001$) in favor of children that did not like the appearance of teeth, and children's knowledge of illness (could describe the color of their teeth) ($X^2 = 21.258$, $p =$ < 0.001) in favor of those who noticed color change, again, if the child's parents were employed or not (p = 0.050, Appendix W) in favor of those whose parents were unemployed. However, the results also showed no statistical significant association between children's gender, and diagnosis of fluorosis, as well as severity of fluorosis ($p =$ 0.431, 0.235, Tables 21 and 22, Appendix P). Finally, the household family size, the household highest education, enrollment in dental program, as well as how parents maintained their children's oral hygiene were not statistically significant($p = 0.516$, 0.997, 0.109, 0.083; Appendix X, Y; Tables 26 and 27).

Summary

The study was guided by two main research questions: (a) what is the prevalence of fluorosis among Nigerian school-aged children; (b) what is the severity of this fluorosis, and is it associated with the fluoride content of the soil, the water or the food? The findings were: the prevalence of fluorosis in children was 86.6% and this was highest in the age group 8-10years. The mean age of children with fluorosis was 10.20 ±SD 2.68 and those without fluorosis was 10.80 ±SD 3.22. The level of severity of fluorosis (Sfl) was significantly associated with the fluoride content in water and soil at 5% and 1% levels of significance respectively. A regression analysis of the relationship between fluoride content in water, soil and food and the level of severity of fluorosis indicated, R^2 (coefficient of determination) of 11.6% showing that the variations in Sfl was explained by the dependent variables. Chi-square test showed significant association between the family SES and fluorosis in children, and this was more in the lower and middle SES (*P*

= 0.009 and 0.014) than in the high SES (*P* = 0.494). The association of children's fluorosis with the variables in RQs 2, 3,4, 5 and 6 were not significant at 95% C.I.

Chapter 5: Discussion, Conclusions, and Recommendations

Introduction

The purpose of this quantitative, cross-sectional study was to examine the cultural and environmental determinants of dental fluorosis among children in the Zing local area, a rural settlement in northern Nigeria. The purpose of this chapter was to discuss the study findings as they relate to findings in the literature, and how this contribute to the current body of knowledge of science. It was also meant to draw conclusions and bring up recommendations that can help the relevant authorities at the local, state and national levels to control the problem of fluorosis in these rural settlements.

This chapter therefore, identified various cultural and environmental factors that could potentially impact the development of dental fluorosis in children as found in this study and elsewhere in the literature. It also, identified the various factors that are associated with this problem, and targeted efforts that could mitigate this problem through positive social change at the community level. To contribute to the current body of knowledge, the chapter tested the Fisher Owens et al., 2007 theoretical model used as foundation in this study, thereby bringing up information that further supports the theory and thus extend the knowledge of science.

Summary of Key Findings of the Study

The ages of child participants ranged from 5 to 15 years, with the most frequent age range of 8 to13 years. The sample was made up of 50.6% males, and 49.4% females, and most of them (68.7%) had lived in the study area for 8 to 13 years (Table 5). Most of the children (77.7%) were from low-SES families (Table 5), and the percentage that ate dawa was 84.8%, while those that ate bambara was 93.7% (Table 5).

Regarding parents characteristics, the ages of the parents and guardians ranged from 11 to 75 years, with 86.2% of them between 21 to 50 years of age. Their household size was 6 to 10 people (55%), and this was most frequent. 76.2% of the parents of the participating children lived together as parents, and 83% of the families ate meals together. The highest education for 51.3% of the households was secondary education. 78.1% of the households used fertilizers to farms, and 96.3% of them stored water in clay pots, while 8.2% of the parents farmed on hilly sites (Table 6).

Concerning socio-demographic characteristics of the community; the study noted that the most available source of water in the community was boreholes and streams which accounted for 77.8% of total water usage (Table 7). There were no dental care programs in the community and no access to a dentist. There also, was no program for the fluoridation of water sources, and the most accessible facilities providing health care services were the primary health care centers (Table 7).

The major findings of the study are as follows: the prevalence of fluorosis in children in the study area was 86.6% (Figure 8), and the prevalence according to gender was 88.2% for males, and 85.0% for females (Figure 9). There was no significant difference between the gender in the diagnosis of fluorosis ($p = 0.432$, Appendix P). The mean age of children with fluorosis was 10.20 years (SD ± 2.68), and the mean age of children without fluorosis was10.80 years (SD ± 3.22). There was no significant age difference between them ($p = 0.181$, Appendix O). Furthermore, the age group with the highest prevalence of fluorosis was 8 to10 years (37.3%), followed by 11 to13 years (33.5%). Thus, 70.8% of children with fluorosis were between the ages of 8 to 13years (Figure 10). The difference between the children with fluorosis and those without fluorosis was accounted for by the length of stay in the community, the age of the student, family SES, student's attitude to health and the student's knowledge of illness, *p* value 0.031, 0.027, <0.001 and <0.001 respectively (Tables 20, 23, 24 and 25).

The mean score of the severity of fluorosis using the TSIF scale was 3.4 which is classified as moderate (Table 10, Appendix F3). There was no statistically significant difference in the severity of fluorosis between the sexes ($X^2 = 4.252$, $p = 0.235$; Table 22). The type of family composition, use of fertilizers, storing water in clay pots and source of water used by the family did not significantly affect children fluorosis (*p* = 0.1021, 0.179, 1.000, 0.2214; Appendix S, T, U and V). However, parent's employment status significantly affected diagnosis of fluorosis in children ($p = 0.050$, Appendix W).

The mean fluoride content in dawa was 7.2mg/l (Table 11) which is above the WHO allowable level of 1.0mg/l. Similarly, the mean fluoride content was 6.6mg/l in bambara (Table 11), 3.5mg/l in water sources, and 6.5mg/l in food and vegetables (Table 10, Figures 13, and15), all of which are above the WHO allowable level of 1.0mg/l. The fluoride content in the soil, however, averaged 0.39 mg/l (Table 10, Figure 12).

As stated previously, there was no significant statistical association between the presence of fluorosis and the consumption of dawa ($X^2 = 0.568$, $p = 0.451$) and there was no significant statistical association between the presence of fluorosis with cropping on hilly sites ($X^2 = 4.62$, $p = 0.258$), and storing of water in clay pots (exact value of 1.000; Tables 13, 15, and 16). Similarly, there was no significant association between fluorosis and bambara consumption and use of fertilizers in farming, $p = 0.06$ and $p = 0.076$, respectively; (Tables 14 and 17).

However, there was a significant statistical association between the severity of fluorosis and the level of fluoride in the water, soil, and food. The regression analysis showed that these variables accounted for 11.6% of the problem (Table 19). The study also, shows that there was a significant association between the presence of fluorosis, and the SES status of the children in the low, and middle status. Furthermore, that there was significant association between the presence of fluorosis with longer length of stay of the children in the study area, better knowledge of the illness, and those with better attitudes toward health (Tables 20, 23, 24, and 25).

Interpretation of the Findings

The study findings revealed that the most frequent age range of children with dental fluorosis was 8 to 13 years and that most of them had lived in the study area for between 8 to 13 years. In the study, the length of stay in the study area and age were significantly associated with the development of dental fluorosis. This finding is consistent with findings of a similar study (Fejerkov, Manji, & Baelum, 1990), which indicated that dental fluorosis is more likely to result during the mineralization of teeth under formation. Thus, exposure to fluoride during this period can predispose subjects to the development of fluorosis. In the same line of thought, Horowitz (1990) indicated that the major determinant of the prevalence and severity of dental fluorosis is related to the concentration of fluoride in water consumed by infants and children during the first 5 years. However, the current study focused on children 5 to 15 years, at which time exposure to the other factors in the environment would already occurred (i.e., mineralization of permanent teeth had taken place), thereby manifesting the effect of this exposure on the development of fluorosis. This is consistent with the findings in the present study where the mean fluoride content in the water sources in the study area was found to be 3.4 mg/l which is higher than the WHO recommended level of 1.0 mg/l. Thus early exposure of children in the study area to water with a high fluoride content could predisposed the sample to developing fluorosis.

The prevalence of fluorosis in children in this study was found to be 86.6%. The prevalence among the two genders was 88.2% for males and 85.0% for females. This was not significant. However, this rate is much higher than findings of a similar study in another part of the country, namely Ibadan in western Nigeria, where the prevalence rate was found to be 11.4% (Ajayi et al., 2012). When compared to other regions of the world, the rate was higher than that in rural India (Saravanan et al., 2008), where the rate was 31.4%. However, the prevalence rate in this study is consistent with the rates found in children living at high altitudes in China; i.e., the Mongol, Kazak, and Yugu areas in the Gansu province, where the rate was 52 - 84% (Cao et al., 1997). The prevalence rate in this study, however, is lower than that found in children living around the Rift Valley in East Africa where it was found to be up to 95.9 %(Kahama et al., 1997).

Although there was no significant association between the presence of fluorosis and farming at higher altitudes in this study, the prevalence rate of 86.6% is comparable to that of children living at high altitudes. In this regard, the study noted that among those cropping on heights, 91% of the children had fluorosis compared with the 9% of children without fluorosis who cropped at higher altitudes (Table 16). Generally, the study area is situated in a hilly and mountainous region, and the weather is usually hot most times of the year (Ambinkanme et al., 2014).

This is consistent with the findings of Cao et al., (1997) that high altitudes exacerbate dental fluorosis, especially among children, noting that under conditions of a lack of oxygen, more fluoride is absorbed and the growth of enamel is unfavorably affected. The high prevalence rate in this study differed substantially from the rate in the western region of Nigeria because of differences in weather and altitude. However, the findings from this study are, lower than the rates in Kenya, East Africa, as there is no evidence of volcanic activity of this region.

In this study, the mean value of fluoride in the various substances were, 3.5mg/l (water), 6.5mg/l (vegetables), 7.2mg/l (dawa), 6.6mg/l (bambara), and 0.39mg/l (soil). These levels (except for the soil) were consistently higher than the WHO-recommended level of 1.0 mg/l. This finding is consistent with previous studies (Petal et al., 2013; Lar & Tejan, 2008) that noted that the fluoride concentration of naturally fluoridated waters varies depending on the geographical location and that in some parts of Africa, this level is as high as 10 ppm. For example, Lar and Tejan (2008) suggested the existence of high fluoride concentrations in the rocks and soil in the Gombe and Kaltungo areas of the upper Benue sedimentary basin. The interaction between water and soil and rock formations leads to dissolution of the constituent fluoride compounds which leads to the presence of soluble fluoride in water sources. This could also explain the high fluorine content in the water, food, vegetables, etc., in this study area, as it is in close proximity to Gombe and Kaltungo.

In the study, the criterion for measuring the severity of dental fluorosis in the sample was the TSIF index. A mean score of 3.4 was obtained in the TSIF range of 0 to 6, which indicated a moderate to severe severity. This is significant and can be explained by the exposure of the sample population to consistently high levels of fluorine in foods, waters, vegetables, etc., in the study area. The TSIF index, developed by Horowitz et al., (1984), was found to discriminate between the prevalence and severity of fluorosis in different groups of communities with different concentrations of fluoride in their drinking water (Horowitz, 1986). This indicates the reliability of the measuring instrument for grading the severity of fluorosis.

In this study, there were no significant difference in the proportion of fluorosis among males (88.2%) and females (85.0%; Figure 9). With the chi-square value of 0.621(p = 0.431), there was no statistical difference in the diagnosis of fluorosis among the sexes. The severity of fluorosis (Table 21) among the different sexes was not significantly different, as the chi-square value was 4.252(p = 0.235). These findings are consistent with similar findings in the study in western Nigeria that did not record any significant difference between the occurrence of fluorosis and gender (Ajayi et al., 2012). In this study it is important to note that there was no significant difference in severity between the sexes; thus, gender may not be connected with genetic and biological influences that could be associated with fluorosis. The factors relating to severity are more likely to be associated with factors in the environment.

Concerning the association of fluorosis and cultural practices, in particular the food culture and other common practices, the study showed no significant association between the development of fluorosis and the consumption of dawa, cropping on heights and use of clay pots for storing water. The test of significance for all of these was $p >$ 0.05, and thus they were not statistically significant. However, the proportion of children who ate dawa and had dental fluorosis was 87.3%, while those who did not eat dawa but had fluorosis was 82.9% (Table 13). In those households that stored water in clay pots and whose children had fluorosis, the proportion was 86.48%, while those that did not use clay pots and whose children had fluorosis was 90% (Table 15).

There was no significant association between eating bambara and the use of fertilizers with fluorosis. Here the proportion of those who ate bambara and had fluorosis was 97.7%, and those who did not eat bambara but had fluorosis was 70.5 % (Table 14). However, concerning the use of fertilizers, those families that used fertilizers and whose children had fluorosis, the percentage was 88.60%, while for those who did not use and whose children had fluorosis, the percentage was 79.66% (Table 17). The proportion of those children who ate dawa and bambara and had fluorosis was very high. This finding is similar to the findings by Cao et al., (1996), who found that brick tea and zanba were food items with high fluoride levels that were linked with fluorosis among Tibetan children. In the present study, the mean fluoride concentration in dawa was 7.2 mg/l, and in bambara, it was 6.6 mg/l. These levels are high when compared with the concentrations in brick tea (2.59±1.73mg/l) and zanba (5.12±2.80mg/l). Thus, the food culture of the population of the present study may also be linked with dental fluorosis.

Furthermore, this study used regression analyses to test the severity of dental fluorosis and the fluoride content of water, soil, and food. The analysis model showed a variance of 11.6%, indicating that the level of fluorosis in the study could be explained by the three variables listed. It was also clear that the F test for predictive association showed a significant predictive association between fluorosis and the three factors, with an F value of 11.580 (p = <0.001), and the analysis showed that the predictive weight of fluoride in soil was significant at t = 5.569 (p = <0.001). These findings are consistent with similar findings in studies by Malde et al., (2011) and Kahama et al., (1997), who associated a high fluoride intake with the fluoride content in soil and vegetables in the volcanic prone Ethiopian Rift Valley. In their study, Malde et al., (2011) noted that the fluoride exposure through food and beverages in young children was due to high amounts of fluoride retained in food prepared with water containing high fluoride levels. Although, in this study there was significant association, it was clear that this significance was more related to the soil and water (Table 19). Particularly, the area with a high soil fluoride content also showed consistent association with high levels of severity and high level of fluorine in water sources and food. This was particularly so in one district, where all three factors were strongly positive. Thus, the severity of fluorosis in the study population could be linked to the levels of fluorine in the soil, water, and food in the study area.

Interpretation of Findings in the Context of the Theoretical Framework

The theoretical framework used in this study was the multilevel conceptual model of influences on children's oral health developed by Fisher-Owens and colleagues (2007). In this model, 22 domains of influences that affect children's oral health were used as a foundation to ground this study. Thus, the factors that influence the development of dental fluorosis in children in the study area were considered according to child-level influences, parent-level influences and community-level influences.

The findings of the study were as follows.

Child Level Influences

The child-level influences examined were biologic and genetic endowment, development, physical and demographic attributes, health behaviors and practices, use of dental care, and dental insurance. To address these influences, 11 questions were asked with at least one directed at each influence. And the study findings were as follows.

To assess genetic and biologic endowment, the age and the sex of each child were determined. The age of children enrolled in the study was fixed at 5 to 15 years. The study finding was that sex had no statistical preferences. The most frequent age of children with fluorosis was between 8 to 13 years, and this did not skew towards a younger age group or to gender to warrant the assumption that a hereditary or genetic disposition was more likely in the development of fluorosis. The gender showed no significant differences in the diagnosis or severity of fluorosis in relation to males or females (Tables 20 and 21). Therefore, the genetic/biological endowment of the children did not influence development of fluorosis.

To assess development, a question on the length of time that each child had lived in the study area was asked. The finding was that the length of stay for the majority of children was 8 to 13 years. The test of significance for the development of fluorosis and length of stay was significant at chi-square = 8.881($p = 0.031$; Table 20) indicating that length of stay, which also relates to age, was significant in the development of fluorosis in this study. Thus, environmental factors, as opposed to hereditary factors, could be associated with fluorosis in the sample involved in this study.

To assess physical and demographic attributes, information about the children's SES was gathered to see if this would influence his/her demographic attributes. The SES of the families showed that 77.7% of children came from low SES backgrounds. The test of significance for the development of fluorosis and SES had an exact value of 0.027, indicating significance (Tables 18 and 23). Therefore, SES contributed to the development of dental fluorosis.

To assess health behaviors and practices, three questions were asked (i.e., When sick you are sick, where do you go for treatment? Do you like the color of your teeth? Can you describe the color of your teeth?). Answers to the first question showed that about 71% of children claimed that they sought medical treatment at health clinics while, 87 of the 267 respondents with fluorosis answered “Yes” to the second question indicating 37.3%. This was also statistically significant, with a chi-square value of 18.112 (p = <0.001; Table 24). This indicates that more than a third of the children felt that having discolored teeth due to fluorosis was considered normal. This indicates a poor health behavior. For the question “Can you described the color of your teeth?” the answer was significant at a chi-square value of 21.258 (p = <0.001). Here, 173 out of 233 with fluorosis (74.2%) could tell if the color of their teeth was black, reddish, white, or yellow (Table 25). This is important as the color in dental fluorosis changes at different stages of the disease. Although they could describe the color of their teeth, they did not see it as abnormal, indicating poor health behavior. Similarly, 60 out of 233 of children with fluorosis (25.7%) could not describe the color of their teeth, indicating poor knowledge of disease.

To assess the use of dental care and dental insurance, questions were asked such as, “Do you regularly attend a dental clinic for check-ups?” and “Are you enrolled in a dental care program?” Out of the 231children with fluorosis who responded, 86.5% of them answered “No” and indicated that there are no dental services in their community. Although the test of significance showed no statistical association at a chi-square value of

0.842 (*p* = 0.657), a similar question for the parents, "Are your children enrolled in dental care?" was also not statistically significant at an exact value of 0.109, indicating that non enrollment of children in dental care did not significantly influence the development of dental fluorosis in this study (Table 26).

Thus, of the six child-level influences explored in this theory as possible contributors to the development of fluorosis, four (4) were found to contribute substantially namely, length of stay in the area, age of child, SES, and health behavior and practices.

Parent Level Influences

The parent-level influences were focused on eight domains of influences, of which five were explored; i.e., family composition, family function, SES, health behaviors, and social support. Regarding family composition, the majority of households surveyed indicated that both parents lived together (76.2%), while 9.7% were single parents, and 1.5% were reconstituted parents (Table 6). The influence here may not be substantial (*p* = 0.1021, Appendix S), as it was thought that single parentage and reconstituted parentage may be more challenging than both parents living together. Such an effect in this study can only be minimal, however, since 76.2% of the parents still lived together.

For family function, questions on family size and if family members ate together were asked. For family size, up to 55% of the families surveyed indicated a family size of 6 to10 (Table 6); others were 11 to 15 people (11.2%) and 16 to 35 people (10.3%). There were also outliers with much higher family sizes. This is an important factor for this study as only 23.4% of the households surveyed had an average family size of 1 to 5.

The majority had household sizes of 6 or more people which is large considering the low SES of most families, and must exert enormous pressure on family resources which is scarce. Regarding whether the family ate together, 82.9% indicated that they did (Table 6). This did not substantially affect the influences at this level. The SES of the families (as already indicated under the child-level influences) contributed substantially to the development of fluorosis in the children as, 77.7% of the families had low SES.

Regarding health behavior, practices, and coping skills, this influence was assessed by asking parents how they maintained their children's oral hygiene and if they were enrolled in a dental care program. Their responses indicated that there was no statistically significant association between the method used for maintaining oral hygiene and fluorosis (Table 27). However, they indicated that there were no dental programs for their children (Table 6). Thus, under this influence, a poor -level health behavior might contribute to childhood fluorosis.

Regarding social support, the study also found that there is minimal support for dental health in the community. For example, there is no access to a dentist and there is no dental insurance scheme in the community (Table 7). At the minimum, of the five parental influences explored, four contributed substantially to the development of poor oral health of children in this community.

Community Level Influences

Regarding community level-influences as previously stated, the study found that there is no dental care system or community dental program available. The only program taking place involves oral hygiene lessons taught in the primary schools. The social and physical environment for dental care is therefore poor, and there are no programs for ameliorating or mitigating the effect of high fluorine content in the available common sources of water in the community. Thus at the minimum, four of the community level influences were found to contribute substantially to the development of fluorosis in this community.

The findings in this study are in agreement with the domains of influences proposed in Fisher-Owen's model for children's oral health. In it, at least 12 of the 22 influences were found to contribute to the development of dental fluorosis in the study area. The influences identified were four at the child level, four at the parental level and four at the community level.

Limitations of the Study

There are some limitations that may affect the generalization of the study findings. For example, due to the extent of the problem of fluorosis in this community, any study focused on dental discoloration would elicit significant interest; thus, children/pupils with the problem and their parents were more likely to volunteer to participate in this study than another type of study. This could cause selection bias in favor of the condition since many participants attended with the hope of getting treatment. To limit this bias, a systematic random selection of study participants was done following the criteria described in the methodology chapter.

Another potential limitation is the non-response error arising from the survey process. For instance, there were inadequate responses on some questions leading to missing data. To control for this, a large sample size was used to prevent the missing data from affecting the validity of the findings.

Because this was a cross-sectional study design, the weakness of inadequate control over rival explanations, such as covariables that could be confused with fluorosis, may impinged on the cases of fluorosis diagnosed. To control for this, the dentist was required to make a definite diagnosis of whether the discoloration was due to fluorosis, dental caries, or other dental conditions. This made the diagnoses more specific and thus ruled out other causes of dental discoloration.

The reliability estimate of the questionnaires as a measurement instrument was assessed to be 92% to 95%, indicating that the questionnaires could accurately elicit correct responses from over 90% of the respondents.

The validity of the measure for grading the severity of fluorosis by the dentist was assessed using the test-retest method. Cronbach's alpha test of validity was 0.948, indicating good reliability; however, the reliability of the measurement instrument cannot always be 100%, and this could affect the diagnosis of the severity of fluorosis.

The estimations of fluoride content in the water, soil, vegetables, dawa, and bambara utilized the spectrophotometric method, whose accuracy is 80% to 92%. This may have affected the validity of the findings and therefore impact their generalizability. Similarly, the representativeness of the sample to the population significantly differed and may therefore affect the generalization of the study findings.

Recommendations

This study resulted in many interesting findings that can contribute to the current body of knowledge regarding fluorosis. However, further research needs to focus on the extent of fluoride contamination of the soil in the study area and the pathways through which it enters the food chain to further extend our knowledge on the development of fluorosis in the study area. It will be interesting to explore why to the contrary, the severity of fluorosis in this study negatively correlates with fluoride content in water. Does this have to do with the method of food preparation or other routes? Again, it will be interesting to further look at the close relationship between fluorosis and the use of fertilizers and the consumption of bambara food in this community.

Implications for Social Change

There are many implications that can be drawn from the findings of this study. The first is positive social change. To address the problem of dental fluorosis in the community, appropriate targeted measures focused at the individual, family, and community levels need to be implemented.

At the individual level, children need to be educated about appropriate health behaviors, including good oral hygiene, practical ways to care for their teeth (e.g., showing them how to use toothpaste and a toothbrush, the need to brush twice a day, how to detect early signs of abnormality in teeth color, and how to determine what is normal dental growth and what should be reported to the dentist), the importance of regular dental check-ups as well as regular medical-check and the need to avoid sweet foods and drinks before bed time to discourage the proliferation of oral micro-organisms.

At the family level, parents need to improve parent-child interaction and create opportunities for this through family meals etc. They need to check their children's dental growth to identify any issues that may require help and institute strict family dental care measures. They should try to improve their family SES by finding ways of engaging in resourceful ventures and to improve the family's level of education. They can enroll their children in dental care programs and address family food habits that promote the development of fluorosis (e.g. reduce their consumption of bambara which was found to be significantly associated with fluorosis, and use alternative sources for improving farm yields such as natural manure instead of fertilizers which were found to be significantly associated with fluorosis).

At the community level, measures should involve the provision of essential services to improve dental care (e.g., monthly dental examinations of school pupils by a dentist and treatment of any identified issues), institution of dental insurance for children aged 2 to 15 years and the provision of a supportive social environment by instituting community health programs such as the flocculation of commonly available water sources (e.g., boreholes), to remove excess fluorine and thus provide safe water for community use. The local government could also improve the general health care services in the community through manpower development and the provision of essential facilities, and they should perform routine/regular checks of the fluorine content in water sources in order to keep them within allowable limits.

At the State/national levels, there should be adequate regulatory measures on the control of fluorine contamination of water sources and trained manpower to safeguard these measures. Policies should also be implemented to control these disorders on a general scale, and resources should be provided to carry out these measures at the community level. If addressed, these changes will bring about positive social change and improve the quality of life in this community.

Conclusion

In this study, cultural and environmental determinants of dental discoloration with a particular focus on dental fluorosis were assessed to explain the high occurrence of this problem in a rural local government area in northern Nigeria. The study was a cross-sectional quantitative study involving the administration of three surveys to children, their parents, and community leaders, to identify various influences on the development of dental fluorosis. Quantitative estimations of fluoride content in various environmental substances (i.e., vegetables, soil, and water) were carried out to ascertain if there could be an association with these levels and the development of fluorosis in this region. Some cultural practices were also explored to ascertain their influence on fluorosis in children.

The study found that the prevalence of dental fluorosis in children in the study area was 86.6%, which is comparable to children living in high mountainous regions, such as some areas in China. There were very strong indications that the fluorosis in these children was associated with the environment, and food culture such as the consumption of bambara, the use of fertilizers in farming and the high fluorine content in the water, food, and soil.

Furthermore, the study found that many influences at the child, parent, and community levels contributed substantially to the development of fluorosis in this region. Therefore, targeted interventions for positive social change in the community should focus on limiting the effect of these influences at the three levels highlighted. Further research is needed to determine the extent of fluoride contamination in the soil and whether it is significantly associated with the severity of fluorosis in this community

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Appendix A: Descriptive Criteria and Scoring System for the Tooth Surface Index of Fluorosis

Numeric Score	Descriptive Criteria
(0)	Enamel shows no evidence of fluorosis.
(1)	Enamel shows definite evidence of fluorosis, namely areas with parchments-white color that total less than one-third of the visible enamel surface. This category includes fluorosis confined only to incisal edges of anterior teeth and cusp tips of posterior teeth ("snow capping").
(2)	Parchment-white fluorosis totals at least one-third of the visible surface, but less than two-thirds.
(3)	Parchment-white fluorosis totals at least two-thirds of the visible surface.
(4)	Enamel shows staining in conjunction with any of the preceding levels of fluorosis.Staining is defined as an area of definite discolouration that may range from light to very dark brown.
(6)	Both discrete pitting and staining of the intact enamel exist.
(7)	Confluent pitting of the enamel surface exists. Large areas of enamel may be missing and the anatomy of the tooth may be altered. Dark-brown stains is usually present.

Note: From Indexes for Measuring Dental Fluorosis by H.S. Horowitz, 1986. *Journal of Public health Dentistry, 46,* 179 – 183.

Appendix B: Questionnaire for Investigating the Determinants of Dental Discoloration in School-Aged Children in Rural Nigeria.*

Survey 1: Child interview**.**

Participant Number #----------   Date----/----/------

1. Gender: { } Male { } Female
2. Birthday ----/---/----
3. Name of village---------
4. How long in area--------years
5. Level of primary education: Grade1 { } Grade 2 { } Grade 3 { } Grade 4 { } Grade 5 { } Grade 6 { }

1. Child-level domains

Physical and demographic attributes.

6. To which race/ethnic group do you belong? black, white, mixed, Asian
7. What is your parent's occupation? farming, civil servant, in government
8. Do you eat breakfast, lunch, and dinner every day? Yes/No
9. Which of these food items do you like eating? dawa, bambara, yam, vegetables
10. Do you like dawa? Yes/No
11. Do you like bambara? Yes/No
12. How often do you eat dawa ? daily, 2-3times weekly, weekly
13. How often do you eat bambara? daily, 2-3times weekly, weekly
14. Do you accompany your parents to farms? Yes/No
15. Where are these farms located? hilly site, low land, valley?

Health behaviors, practices and perceptions

16. When you are sick, which of these places do you like to go for treatment?

    Health clinic, chemist, herbal home, other.

17. Can you tell me the color of your teeth? white, yellow, reddish, black, other.
18. Do you like the appearance of your teeth? Yes/No
19. Have you noticed any color changes on your teeth? Yes/No
20. If yes, how long ago?.....

Dental Care and Hygiene

21. How do you clean your teeth? Toothpaste on a brush, chewing stick, charcoal
22. Do you do this every day? Yes/No
23. Do you regularly attend a dental clinic for check- ups? Yes/No
24. When was the last time you attended a dental clinic? ……
25. Are you taught about oral hygiene in school? Yes/No.

Dentist Inspection of Teeth

26. Do the teeth reflect fluorosis? Yes/No
27. If no do they reflect dental caries? Yes/No
28. What is the severity of fluorosis using the TSIF scale? 0, 1, 2, 3 ,4, 5, 6

*This survey was adapted from the childhood oral health model using the 22 domains of influences on childhood oral health.

Survey 2: Household parent/guardian interview

1. Participant identification

Participant Number #-------------- Date-------/------/------

1. Gender : { } Male { } Female
2. Birthday : ------/------/-------
3. How long in area(name of village)-------years
4. Level of education: { } Did not go to school { } Can read/write { } Primary school { } Secondary school { } Technical school { } Graduate school
5. Are you married? { } Yes { } No [if yes, ask #6, if no go to #7]
6. Spouse's occupation? ---

2. Family-level domains

Family composition

7. What is your family composition? Single parent, reconstituted parent, both parents together.
8. How many of you live together in your household?.........

Family function

9. Which religion does your household practice? Christianity, Moslem, None
10. Did you breast feed your children at birth? Yes/No (to be answered if responder is the mother)
11. How long(number of months) did you breast feed your child in this study? ……. (to be answered if responder is the mother)

12. Do you usually eat meals together as a family? Yes/No
13. Which common food types do you usually eat as family? Rice, yam, dawa, bambara, vegetables
14. How often do you eat dawa? rarely, sometimes, most of the time, every day.
15. What about bambara? rarely, sometimes, most of the time , every day
16. What is your source of water use in your household? borehole, stream, public tap water, river
17. Do you also drink this water? Yes/No.

SES status

18. What is the highest education in the household? degree holder, secondary, primary education.
19. What is the source of your family income? trading, farming, from government,
20. Do you practice farming as occupation? Yes/No
21. Where do you commonly cultivate your farms? hilly sites, level ground, valley sites
22. Which common foods do you cultivate?
23. Do you use fertilizers in cultivating your farms? Yes/No
24. Are you employed presently? Yes/No

Health behaviors and practices of family

25. Are your children enrolled in dental care program? Yes/No

26. How often do they attend these clinics? every 3 months, every 6 months, every year.
27. How do you maintain your children's oral hygiene? toothpaste and brush, chewing stick, other

Culture

28. What language do you speak at home? English , Hausa , others
29. Do you use of clay pot for storing water or cooking? Yes/No.

Survey 3: Community leader interview

Community-level domain (neighborhood) to be answered by local council officials, and head teachers of participating schools

Participant identification

Participant Number #-------------- Date-------/------/------

1. Gender : { } Male { } Female
2. Birthday : ------/------/-------
3. How long in area(name of village)-------years
4. Level of education: { } Did not go to school { } Can read/write { } Primary school { } Secondary school { } Technical school { } Graduate school
5. Occupation ………………..

Social capital

6. Which social amenities are available in the community that people share? water, electricity, roads , other
7. What is the source of water available in the community? stream, borehole, municipal treated water, other
8. Which water source is most frequently used by the people? stream, borehole, municipal water.
9. Are these waters fluoridated? Yes/No

Communioty oral health environment

10. Is there a dental care program in the community? Yes/No
11. How often are these services provided? Once year, twice a year, every quarter.

Dental / health-care system available

12. Do you have access to dentists in the community? Yes/No
13. Do you have access to doctors in the community? Yes/No
14. What type of health facilities do you have in the community? primary care centers, hospitals, specialist hospitals

Appendix C: Checklist for the Field Investigation of Fluorosis Using the Spectrophotometric Method

1. What is the fluoride content (dose) of water sources in the community?

2. What is the fluoride content (dose) of soil specimens from farming sites?

3. What is the fluoride content (dose) of common food types grown in the community?

Appendix D: Form 1 Record of Dentist Findings Using Dean's Grading Index

		Description of severity						
Participant's number.	Does participant have dental fluorosis? Yes/No	Normal (enamel is translucent, smooth, glossy, pale, creamy or white in color	Questionable (enamel shows slight aberration with few white flecks to occasional white spots)	Very mild (enamel has small, opaque, paper-white areas irregularly in about ¼ of tooth surface	Mild (enamel shows more opaque area but not upto 50% of tooth)	Moderate (all enamel surface is affected, surface shows wear, brown stains are present)	Severe (all enamel surface is affected, hypoplasia marked, discrete or confluent pitting, brown stains widespread, corroded-like appearance)	Level of severity.

Appendix E: Form 2 Dentist Record of Observations Using TSIF Scale

		Description of severity							
Participant number	Does participant have dental fluorosis? Yes/No	0. Normal enamel shows no evidence of fluorosis	1. Enamel shows areas with parchments white color less than 1/3 of visible enamel surface	2. Parchment white fluorosis totals at least 1/3 of visible surface	3. Parchment white fluorosis is on at least 2/3 of surface	4. Enamel shows staining in conjunction with preceding levels; stains range from light to very dark brown	5. Both discrete pitting and staining of enamel exist	6. Confluent pitting of enamel surfaces; large areas of enamel may be missing; dark brown stains present	Level of severity

Appendix F: Brief on Orientation Meeting With the PTA (Parents Teachers' Children's Forum)

Preamble

Good morning ladies and gentlemen, parents and children. My name is Ogbudu Ada, a doctoral degree student at Walden University in the United States of America. I am doing a research project to learn about factors that can impact teeth color in children and I am glad for the opportunity given me to interact with you this morning in order to enable me brief you about this study.

About the Study

Tooth discoloration in children is a public health problem affecting the quality of health in developing countries such as Nigeria. Indeed, the intensity of this problem in Nigeria is put at a prevalence of 11.4%. This is quite high. Some of the major causes of teeth discoloration in children are fluorosis (commonly referred to as molting of teeth), caries (tooth decay from infection), certain type of drugs etc. However, in this study, I intend to focus mainly on the effect caused by fluorosis. Thus, the study will look at those factors that expose a child in this community to the possibilities of developing dental fluorosis.

In this situation, I shall focus on factors related to the child, parents, and the community. For each of these levels, there are factors that can contribute to developing tooth discoloration such poor oral hygiene by children, types of food eaten, type of water used for cooking, availability of good water supply in the community, and availability of oral health services in the community. Therefore the study will look at these factors as they impact teeth discoloration in children in the study.

What to Expect in the Study

To enable me to carry out this study, I am going to administer three surveys beginning with that on the children, followed by their parents and then community leaders. For the children survey, I will also ask a dentist to inspect their teeth to determine whether they have teeth discoloration from fluorosis or caries. This is only inspection and not dental examination. This is only for the purposes of finding out if the child has tooth discoloration or not and not for any medical care. The child's parent will also be asked to be present when we are carrying out this inspection. For the second survey which will focus on the household, one of the child's parents (preferably the mother) will answer the questions and the third survey will be answered by community leaders, like the head teachers of the schools involved in the study as well as the local government chairman and secretary.

Selection for Participation

Participation in the study will be based on age and how long a child has lived in the community. All children who are selected from each class will be invited with their parents to participate in a briefing that I will hold in 3days time in the school assembly hall. During this briefing, the participant s will be further briefed on what an informed consent is before being given consent and assent forms to sign. Only those parents and children who return their forms will be invited to participate in the study.

Feedback. The findings of the study will be communicated to all stakeholders and the teachers, parents and children of each of the participating schools.

Conclusion

Let me therefore thank you all for the interest in this study. Thank you

Appendix G: Brief to Participants, Parents, and Children

Introduction

Good afternoon ladies and gentlemen and welcome to this briefing for participants. This is a follow-up of the briefing I had with the PTA some days ago where I mentioned the importance of this study. This follow-up briefing is to provide you with additional information about the study to enable you make an informed decision as to whether you wish to participate in the study. Therefore, I will further explain to you the nature of participation in the study, what is an informed consent, as well as explain the procedure for participation and selection of participants for the study.

Voluntary Nature of Participation

This study is voluntary. I will respect your decision of whether or not you want to be in the study. To participate, every parent and child participant will need to give consent before being enrolled in the study. After giving consent and assent now, you or your child can still change your mind later if you no longer feel obliged to participate. Any child who feels stressed during the study may stop at any time. In order to help me progress in the study process, I will now explain what an informed consent and assent means.

Informed consent/assent form and process. The informed consent process involves me providing you with enough information to enable you to understand what the study process is, such as the risk you may be exposed to during the study so that you can make an informed decision to participate. In this let me state that the study does not pose any risk to participants. The only minimal risk may be minor discomforts that you might encounter in daily life, such as fatigue or becoming upset. Being in this study would not pose risk to your child's safety or well-being.

I will like to highlight the following areas in the consent form for you to note.

Procedure. Every participant will be asked to answer questions from the survey questionnaire. Each child will also have his/her teeth inspected by a dentist. This is not a dental examination or any dental services but it is only for the purposes of helping me to know which children have dental discoloration. This exercise may last for 20 minutes for each child, but to help me to cross-check the result of the dentist inspection, every 10th child inspected will again be selected for re-inspection of his/her teeth.

Sample questions. Some sample questions will include the following: (a) What is the color of your teeth, (b) Are you taught oral care in school, (c) Do you use fertilizers in cultivating your farms, (d) Do you use clay pots to store water, (e) What is the source of water available in the community, and (f) Is there a dental care program in the community?

Risks and benefits of study. As stated, the study may involve only minimal discomfort such as fatigue and discomfort of opening mouth to be inspected. No other risks are envisaged. The study will enable us to find ways of helping to control tooth discoloration in children and bring this knowledge to relevant authorities.

Payments. You will be rewarded with a biro at the end of the exercise not as payment but as a sign of my appreciation for participating.

Privacy. Any information you provide will be kept confidential. I will not use your personal information for any other purpose outside of this research project. Also, I will not include your name or anything else that could identify you in the study reports.

Data will be kept secure by a secret password only known to me. Data will be kept for a period of at least 5 years, as required by the university.

Selection/Enrollment of Participants

Once you have decided to participate, you will be required to fill out a consent or assent form which I will give to you at the end of this briefing. For children participants, both parent consent form and the child assent form must be filled out. The completed forms must be returned to me within 2 weeks in the assembly hall of the school premises. On returning the forms, your name and address will be documented in a register that I have created to enable me determine the number of participants who are willing to participate in the study.

From those who have returned their forms, I will invite every third child and his/her parent to be enrolled in the study using the study criteria. This criteria is that the child selected should be between the ages of 5 to 15years, and born and reared in Zing. Those enrolled will then be invited to participate in the study.

The survey process. The survey process will start with enrolling all those children and their parents invited that meet the selection criteria. This will be done in one classroom in the school premises.

Role of dentist. For purposes of emphasis, I wish to explain that during the study, those children who have been selected for the study will have their teeth inspected by a dentist to know their color. This is not dental examination or any dental services but is meant to only help the dentist know if the teeth are discolored. This inspection will be done in my presence and the child's parent. And every 10th child will have the inspection repeated.

Commencement of study. The study will commence in 2 weeks immediately after participants return their consent and assent forms. We must also agree that the time for our meetings shall be after the school hours, so that school activities are not affected. Conclusion: Thank you for finding time to attend this orientation meeting. If you have questions, feel free to ask me for any clarification. Let me also remind you I will now distribute the consent forms to you which you will fill and return to me within 2 weeks. I will be placing a labeled box in the school assembly hall for you to drop your retuned forms. Thank you.

Appendix H: Reliability Statistics.

Table H1

Table of Reliability Statistics Showing Summary Item Statistics

	Mean	Minimum	Maximum	Range	Maximum / Minimum	Variance	N of Items
Item means	3.900	3.680	4.120	.440	1.120	.097	2

Table H2

Table of Reliability Statistics Showing Calculation of Item-total Statistics

	Scale mean if item deleted	Scale variance if item deleted	Corrected item-total correlation	Squared multiple correlation	Cronbach's alpha if item deleted
Dentist grading of severity using TSIF scale	4.1200	4.193	.901	.812	.
Repeated dentist grading of severity using TSIF scale for selected pupils	3.6800	4.310	.901	.812	.

Table H3

Table of Calculated Reliability Statistics

Cronbach's alpha	Cronbach's alpha based on standardized items	N of Items
.948	.948	2

Appendix I: Table of Mean Age of Participating Children by Gender**.**

	Gender	N	Mean	Std. Deviation	Std. Error Mean
Age in years	Male	136	10.632	2.8644	.2456
	Female	133	9.880	2.6084	.2262

Note: *N* = 269, *p* = 0.025 (Independent sample test).

Appendix J: Table of Gender Characteristics According by Classgrade.

Gender	Grade 1	Grade 2	Grade 3	Grade 4	Grade 5	Grade 6	Total
Male	10(14.7)	21(18.7)	26(25.3)	20(24.3)	13(15.2)	46(37.9)	136(136.0)
Female	19(14.3)	16(18.3)	24(24.7)	28(23.7)	17(14.8)	29(37.1)	133(136.0)
Total	29(29.0)	37(37.0)	50(50.0)	48(48.0)	30(30.0)	75(75.0)	269(269.0)

Note: N = 269, $X^2 = 9.236$, $p = 0.10$, expected count in parentheses.

Appendix K: Table of Seeking Treatment When Ill

Gender	Chemist	Health clinic	Herbal home	Others	Total
Male	37(35.4)	97(97.6)	2(2.0)	0(1.0)	136(136.0)
Female	33(34.6)	96(95.4)	2(2.0)	2(1.0)	133(136.0)
Total	70(70.0)	193(193.0)	4(4.0)	2(2.0)	269(269.0)

Note: N = 269, p = 0.532, expected count in parentheses. As conditions for use of chi square were not met, *Winpepi* was used for exact fisher test p = 0.6829.

Appendix L: Table of Student's Preferred Method of Cleaning Teeth.

Gender	Charcoal	Chewing Stick	Chewing Stick/Toothpaste on brush.	None	Toothpaste on brush	Total
Male	1(1.0)	41(31.3)	4(3.0)	1(1.0)	89(99.1)	136(136.0)
Female	1(1.0)	21(30.7)	2(3.0)	1(1.0)	108(97.9)	133(133.0)
Total	2(2.0)	62(62.0)	6(6.0)	2(2.0)	197(197.0)	269(269.0)

Note: N = 269, $X^2 = 9.739$, p = 0.083, expected count in parentheses. However as conditions for chi-square were not met, exact fisher's test was used, p = 0.0239. Cell by cell p value = 0.004 significant for toothpaste on brush in favor of female (+0.02) to male (-0.02).

Appendix M: Table Showing Mean of Children Taught Oral Hygiene and Fluorosis.

	Taught Oral Hygiene	N	Mean	Std. Deviation	Std. Error Mean
Fluorosis	Yes	243	1.132	0.3388	.0217
	No	22	1.182	0.3948	.0842

Note: N = 267, p = 0.517(independent t – test)

Appendix N: Table Showing Mean of Children that Eat Breakfast, Lunch and Dinner Daily by Gender**.**

	Eats breakfast, lunch, dinner daily	N	Mean	Std. Deviation	Std. Error Mean
Gender	Male	83	1.482	0.5027	.0552
	Female	185	1.497	0.5013	.0369

Note: N = 268, p = 0.817 (independent t – test).

Appendix O: Table Showing Mean Age of Fluorosis in Children.

	Diagnosis of Fluorosis	N	Mean	Std. Deviation	Std. Error Mean
Age in years	Yes	233	10.172	2.6807	.1756
	No	36	10.833	3.2205	.5367

Note: N = 269, p = 0.181(independent t – test)

Appendix P: Table Showing Diagnosis of Fluorosis and Gender.

	Gender	N	Mean	Std. Deviation	Std. Error Mean
Diagnosis Fluorosis	Male	136	1.118	.3234	.0277
	Female	133	1.150	.3588	.0311

Note: N = 269, p = 0.432 (independent t – test).

Appendix Q: Table Showing Frequency of Fluorosis in Children and Household Size

Household size	Fluorosis Yes	Fluorosis No	Total
2	2	1	3
3	12	1	13
4	16	6	22
5	20	1	21
6	31	6	37
7	28	4	32
8	26	6	32
9	14	1	15
10	24	2	26
11	7	2	9
12	7	1	8
13	1	1	2
14	4	0	4
15	6	0	6
16	2	0	2
18	6	0	6
20	4	0	4
21	1	1	2
22	1	0	1
23	1	0	1
25	3	1	4
28	1	0	1
30	2	0	2
40	0	1	1
50	2	0	2
70	1	0	1
100	1	0	1
130	1	0	1
NA	9	1	9
Total	233	36	269

Appendix S: Table of Family composition and Fluorosis in Children

Family composition	Fluorosis in children		Total
	Yes	No	
Both parents together	203	27	230
Reconstituted parents	4	0	4
Single parent	22	8	30
No response	4	1	5
Total	233	36	269

Note: N=269, $X^2 = 6.108$, $p = 0.106$. Chi-square conditions not met, fisher p value = 0.1021

Appendix T: Table of Use of Fertilizers (parents' survey) and Fluorosis in Children

Use of fertilizers	Fluorosis in children		Total
	Yes	No	
Yes	185	25	210
No	48	11	59
Total	233	36	269

Note: N=269, p=0.179.

Appendix U: Table of Use of Clay Pots and Fluorosis in Children

Use of clay pots	Fluorosis in children		Total
	Yes	No	
Yes	224	35	259
No	9	1	10
Total	233	36	269

Note: N = 269, p = 1.000 (fisher test)

Appendix V: Table of Water Sources and Fluorosis in Children.

Water sources	Yes	No
Borehole	128	14
Borehole and other sources	46	12
Public tap and other sources	18	3
Streams and other sources	41	7
Total	233	36

Note: Other sources include river, well, etc. fisher's $p = 0.2214$, $X^2 = 4.267$, $p = 0.254$(computed using winpepi statistical software).

Appendix W: Table of Parents Employed and Fluorosis in Children

Employed	Fluorosis in children		Total
	Yes	No	
Yes	111	12	123
No	124	24	148
Total	233	36	269

Note: N = 269, Pearson p = 0.037(chi-square conditions not met), fisher exact p = 0.050 mid p = 0.037 (from Epi info statistical software).

Appendix X: Table Household Family Size and Fluorosis in Children.

	Households	Fluorosis
Household size	Freq.	freq.
Below 6	63	50
6 – 10	148	123
11 – 15	30	23
16 - 20	12	12
21 – 25	7	6
26 and above	9	17
Total	269	233

Note: fisher's p = 0.517, X^2 = 4.235, p = 0.516(computed using winpepi statistical software).

Appendix Y: Table Household Highest Education and Fluorosis in Children.

Household highest education	Education Freq.	Fluorosis Freq.
Degree	59	54
Diploma/NCE	3	2
Secondary	138	118
Primary	32	26
No formal education	3	2
No response	34	31
Total	269	233

Note: fisher's $p = 0.997$, chi-square conditions not met (computed using winpepi statistical software).

Appendix Z: Parent Consent Form for Research (for Parent of Participating Child).

Your child is invited to take part in a research study on tooth discoloration in children. The researcher is inviting every third child from each of the classes in eight primary schools (Ibrahim Sambo, Sabongari, Dangong, Bitako, Yonko, Tadovah, Panki and Kwapo Gida) who are between the ages of 5 to15years and who were born and are resident in the Zing community to be in the study. This form is part of a process called “informed consent” to help you understand what the study is about before deciding whether to allow your child to take part. This study is being conducted by a researcher named Ogbudu Ada, who is a doctoral student at Walden University.

Background Information

The purpose of this study is to examine what factors may impact tooth discoloration in Zing children.

Procedure: If you agree to allow your child to be in this study, your child will be asked to answer some questions on: (a) oral care, (b) type of foods commonly eaten, and (c) how long he/she has lived in the community.

His/her teeth will be inspected by a dentist to see their condition. This is not really a dental examination but just an inspection to look at the color of the teeth. The inspection may be done twice for every 10th child inspected to help validate the findings of the dentist. The whole exercise will take about 20 to 25 minutes to complete.

Here are some sample questions: (a) what is the color of your teeth, and (b) Are you taught oral care in school?

Voluntary Nature of the Study

This study is voluntary. I will respect your decision of whether or not you want your child to be in the study. Of course, your child's decision is also an important factor. After obtaining your consent, I will explain the study to the children and let each child decide if they wish to volunteer. If you decide to consent now, you or your child can still change your mind later. Any child who feel stressed during the study may stop at any time.

Risks and Benefits of Being in the Study

Being in this type of study involves some risk of minor discomfort that your child might encounter in daily life, such as fatigue or becoming upset. Being in this study would not pose any risk to your child's safety or well-being. The study will enable me to suggest ways of helping to control tooth discoloration in children and bring this knowledge to relevant authorities. During the study, the dentist may be impelled to share issues of obvious concerns with parents and offer advice. In this regard, parents can contact any dentist or facility of their choice such as the General Hospital in Zing provided the services are not provided by the dentist involved in this study.

Payment. The child shall be rewarded with a biro as a token of my appreciation for participating in the study.

Privacy. Any information your child provides will be kept confidential. I will not use your child's information for any purposes outside of this research project. Also, I will not include your child's name or anything else that could identify your child in any reports of the study. The only time I may need to share your child's name or information would be if I learn about possible harm to your child or someone else. Data will be kept secure by secret password known only to me. Data will be kept for a period of 5 years, as required by the university.

Contacts and Questions

You may ask any questions you have now. Or if you have questions later, you may contact me via email at ogbudu.ada@waldenu.edu . If you want to talk privately about your child's rights as a participant, you can call Dr. Leilani Endicott. She is the Walden University staff member who can discuss this with you. Her phone number is 001-612-312-1210. Walden University's approval number for this study is 02-03-16-0173727 and it expires on 02-01- 2018. I will provide an extra copy of this form for you to keep.

Statement of Consent:

I have read the above information and I feel I understand the study well enough to make a decision about my child's involvement in this optional research project. By signing below I understand that I am agreeing to the terms described above.

Name of parent giving consent --

Name of child ---

Date of consent --

Signature of parent ---

Signature of researcher ---

Appendix 1: Assent Form for Research (to be read to the child)

Hello, my name is Ogbudu Ada and I am doing a research project to learn about factors that can impact teeth color. I am inviting you to join my project. I am inviting every third child from each of the classes in eight primary schools (Ibrahim Sambo, Sabongari, Dangong, Bitako, Yonko, Tadovah, Panki and Kwapo Gida) who are between the ages of 5 and 15 and were born and reared in the Zing community to be in the study. I am going to read this form to you. I want you to learn about the project before you decide if you want to be in it.

Who I Am

I am a student at Walden University. I am working on my doctoral degree

About the Project

If you agree to be in this project, you will be asked to answer some questions on: (a) oral care, (b) type of foods commonly eaten, and (c) how long you have lived in the community. Your teeth will be inspected by a dentist to see their condition. This is not really a dental examination but an inspection to look at the color of the teeth. This inspection may be done twice for every tenth child inspected to help me know that the dentist is collecting the right information. The whole exercise will take about 20 to 25 minutes to complete.

Here are some sample questions: (a) what is the color of your teeth, (b) Are you taught oral care in school?

It's your choice. You don't have to be in this project if you don't want to. If you decide now that you want to join the project, you can still change your mind later. If you want to stop, you can.

Being in this project might make you tired or stressed, just like when you play with your friends. But I am hoping that this project might help others by helping them know how to maintain healthy teeth. You will be rewarded with a biro at the end of the exercise.

PRIVACY

Everything you tell me during this project will be kept private. That means that no one else will know your name or what answers you gave. The only time I have to tell someone is if I learn about something that could hurt you or someone else.

ASKING QUESTIONS

You can ask me any questions you want now. If you think of a question later, you or your parents can reach me at ogbudu.ada@waldenu.edu . If you or your parents would like to ask my university a question, you can call Dr. Leilani Endicott. Her phone number is 001-612-312-1210.

I will give you a copy of this form. Please sign your name below if you want to join this project.

Name of Child ______________________________

Child Signature ______________________________

Date ______________________________

Researcher Signature ______________________________

Appendix 2: Consent Form *(*for Parent/Guardian Participating*)*

You are invited to take part in a research study on tooth discoloration in Zing children. The researcher is inviting every parent/guardian of every child selected for participation in the study from the eight primary schools of Ibrahim Sambo, Sabongari, Dangong, Bitako, Yonko, Tadovah, Panki and Kwapo Gida to be in the study.

This form is part of a process called "informed consent" to allow you to understand this study before deciding whether to take part. This study is being conducted by a researcher named; Ogbudu Ada, who is a doctoral student at Walden University.

Background Information

The purpose of this study is to examine what factors impact on tooth discoloration in children.

Procedures. If you agree to be in this study, you will be asked to answer some questions on: (a) possible inputs on environmental sources of fluoride in your households, and (b) You will be requested to answer questions on your water sources and some common food practices.This may take about 20 to 25 minutes to complete.

Here are some sample questions: (a) Do you use fertilizers in cultivating your farms, (b) Do you use clay pots to store water?

Voluntary Nature of the Study

This study is voluntary. I will respect your decision of whether or not you choose to be in the study. If you decide to join the study now, you can still change your mind later. You may stop at any time if you no longer wish to continue in the study.

Risks and benefits of being in the study. Being in this type of study involves some risk of minor discomfort that can be encountered in daily life, such as fatigue, stress or becoming upset. Being in this study would not pose risk to your safety or wellbeing. The study will help me to suggest ways of helping to control tooth discoloration in children and bring this knowledge to relevant authorities.

Payment. You shall be rewarded with a biro at the end of the exercise.

Privacy. Any information you provide will be kept confidential. I will not use your personal information for any purposes outside of this research project. Also, I will not include your name or anything else that could identify you in the study reports. Data will be kept secure by secret password only known to me. Data will be kept for a period of at least 5 years, as required by the university.

Contacts and Questions

You may ask any questions you have now. Or if you have questions later, you may contact me via ogbudu.ada@waldenu.edu . If you want to talk privately about your rights as a participant, you can call Dr. Leilani Endicott. She is the Walden University representative who can discuss this with you. Her phone number is 001-612-312-1210. Walden University's approval number for this study is 02-03-16-0173727 and it expires on 02-01-2018.

I will give you a copy of this form to keep.

Statement of consent. I have read the above information and I feel I understand the study well enough to make a decision about my involvement. By signing below, I understand that I am agreeing to the terms described above.

Participant’s signature ---

Researcher’s signature ---

Date of consent ---

Appendix 3: Consent Form (for Community Leaders Participating)

You are invited to take part in a research study on tooth discoloration in Zing children. The researcher is inviting community leaders in Zing (i.e., the Zing local government area chairman and secretary, head of the works department, and head teachers of the eight primary schools of Ibrahim Sambo, Sabongari, Dangong, Bitako, Yonko, Tadovah, Panki and Kwapo Gida to be in the study.

This form is part of a process called “informed consent” to allow you to understand this study before deciding whether to take part.

This study is being conducted by a researcher named; Ogbudu Ada, who is a doctoral student at Walden University.

Background Information

The purpose of this study is to examine what factors impact on tooth discoloration in children.

Procedures. If you agree to be in this study, you will be asked to answer some questions on: (a) types of social amenities available in the community, (b) I will also be asking you to answer questions on some community health programs carried out in the community. This may take about 20 to 25 minutes to complete.

Here are some sample questions: (a) what is the source of water available in the community, (b) Is there a dental care program in the community?

Voluntary Nature of the Study

This study is voluntary. I will respect your decision of whether or not you choose to be in the study. If you decide to join the study now, you can still change your mind later. You may stop at any time if you no longer wish to continue in the study.

Risks and benefits of being in the study. Being in this type of study involves some risk of a minor discomfort that can be encountered in daily life, such as fatigue, stress or becoming upset. Being in this study would not pose risk to your safety or wellbeing. The study will enable me to suggest ways of helping to control tooth discoloration in children and bring this knowledge to relevant authorities.

Payment. You will be rewarded with a biro at the end of the exercise.

Privacy. Any information you provide will be kept confidential. I will not use your personal information for any purposes outside of this research project. Also, I will not include your name or anything else that could identify you in the study reports. Data will be kept secure by secret password only known to me. Data will be kept for a period of at least 5 years, as required by the university.

Contacts and Questions:

You may ask any questions you have now. Or if you have questions later, you may contact me via ogbudu.ada@waldenu.edu . If you want to talk privately about your rights as a participant, you can call Dr. Leilani Endicott. She is the Walden University representative who can discuss this with you. Her phone number is 001-612-312-1210. Walden University's approval number for this study is 02-03-16-0173727 and it expires on 02-01-2018. I will give you a copy of this form to keep.

Statement of Consent

I have read the above information and I feel I understand the study well enough to make a decision about my involvement. By signing below, I understand that I am agreeing to the terms described above.

Participant's signature ---

Researcher's signature --

Date of consent --

Appendix 4: Assent Form for Pilot Study (to be Read to the Child)

Hello, my name is Ogbudu Ada and I am doing a research project to learn about factors that can impact teeth color. I am inviting you to join in this pilot study which is to help me assess how correctly participants respond to the questionnaires used in this study project. I am inviting children from your primary school who are between the ages 5 and15 to be in this pilot study. I am going to read this form to you. I want you to learn about the project before you decide if you want to be in this pilot study.

Who I Am

I am a student at Walden University. I am working on my doctoral degree

About the Project

If you agree to be in this pilot study, you will be asked to answer questions on: (a) oral care, (b) Types of food commonly eaten, and (c) How long you have lived in the community.

Your teeth will be inspected by a dentist to see their condition. This is not really a dental examination but just an inspection to look at the color of the teeth. The whole exercise will take about 20 to 25 minutes to complete.

Here are some sample questions: (a) what is the color of your teeth, and (b) Are you taught oral care in school?

It’s your Choice

You don’t have to be in this project if you don’t want to. If you decide now that you want to join the project, you can still change your mind later. If you want to stop, you can. Being in this project might make you tired or stressed, just like when you play with your friends. But I am hoping this project might help others by helping them know how to maintain healthy teeth. You will be rewarded with a biro at the end of the exercise.

Privacy. Everything you tell me during this project will be kept private. That means that no one else will know your name or what answers you gave. The only time I have to tell someone is if I learn about something that could hurt you or someone else.

ASKING QUESTIONS

You can ask me any questions you want now. If you think of a question later, you or your parents can reach me at ogbudu.ada@waldenu.edu . If you or your parents would like to ask my university a question, you can call Dr. Leilani Endicott. Her phone number is 001-612-312-1210.

I will give you a copy of this form. Please sign your name below if you want to join this project.

Name of Child ______________________________

Child Signature ______________________________

Date ______________________________

Researcher Signature ______________________________

Appendix 5: Consent Form for Pilot Study (for Parent/Guardian Participating)

You are invited to take part in a pilot study to assess how correctly participants can answer to questions administered to them in the questionnaire designed for the study on factors that impact on tooth discoloration in Zing children. I am inviting every parent/guardian of every child selected for participation in the pilot study to be in the study. This form is part of a process called "informed consent" to allow you to understand this study before deciding whether to take part.

This pilot study is being conducted by a researcher named; Ogbudu Ada, who is a doctoral student at Walden University.

Background Information

The purpose of the pilot study is to assess how correctly participants respond to questions on the questionnaire on factors that impact on tooth discoloration in children.

Procedure. If you agree to be in this pilot study, you will be asked to answer some questions on: (a) Possible inputs on environmental sources of fluoride in your households, (b) You will also be requested to answer questions on your water sources and some common food practices**.** This may take about 20 to 25 minutes to complete.

Here are some sample questions: (a) Do you use fertilizers in cultivating your farms? Yes/No**,** (b) Do you use clay pots to store water?

Voluntary Nature of the Study

This study is voluntary. I will respect your decision of whether or not you choose to be in the study. If you decide to join the study now, you can still change your mind later. You may stop at any time if you no longer wish to continue in the study.

Risks and Benefits of Being in the Study

Being in this type of study involves some risk of minor discomfort that can be encountered in daily life, such as fatigue, stress or becoming upset. Being in this study would not pose risk to your safety or wellbeing.

The study shall enable me to suggest ways of helping to control tooth discoloration in children and bring this knowledge to relevant authorities.

Payment. You shall be rewarded with a biro at the end of the exercise.

Privacy. Any information you provide will be kept confidential. I will not use your personal information for any purposes outside of this research project. Also, I will not include your name or anything else that could identify you in the study reports. Data will be kept secure by secret password only known to me. Data will be kept for a period of at least 5 years, as required by the university.

Contacts and Questions

You may ask any questions you have now. Or if you have questions later, you may contact me via ogbudu.ada@waldenu.edu . If you want to talk privately about your rights as a participant, you can call Dr. Leilani Endicott. She is the Walden University representative who can discuss this with you. Her phone number is 001-612-312-1210. Walden University's approval number for this study is 02-03-16-0173727 and it expires on 02-01-2018.

I will give you a copy of this form to keep.

Statement of Consent

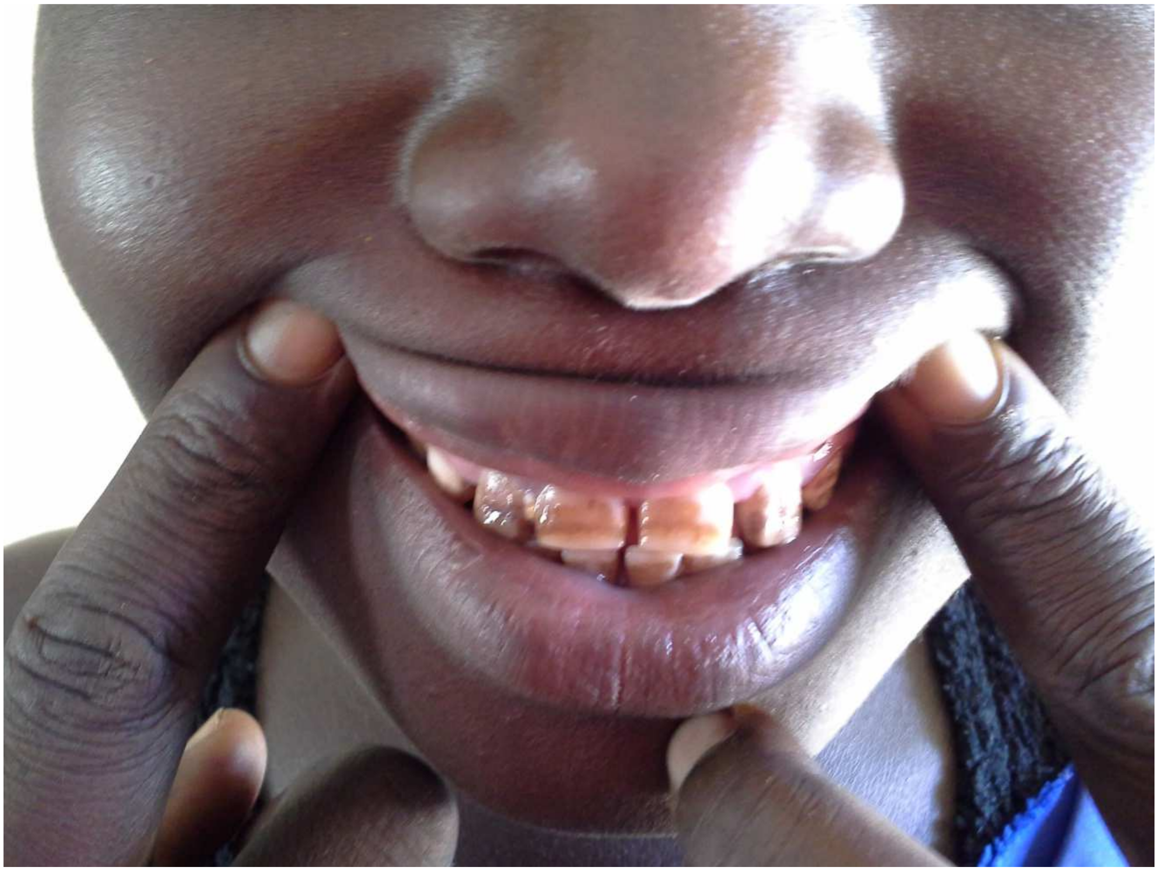
I have read the above information and I feel I understand the study well enough to make a decision about my involvement. By signing below, I understand that I am agreeing to the terms described above.

Participant's signature --

Researcher's signature --

Date of consent --

Field Picture of Severe Dental Fluorosis in Study Population (TSIF 4)



Field Picture of Mild Dental Fluorosis in Study Population (TSIF 2)