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Dental fluorosis, dental caries, and oral health related quality of life (OHRQoL) in the United States

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BOSTON UNIVERSITY
HENRY M. GOLDMAN SCHOOL OF DENTAL MEDICINE

DISSERTATION

**DENTAL FLUOROSIS, DENTAL CARIES, AND ORAL HEALTH RELATED
QUALITY OF LIFE (OHRQoL) IN THE UNITED STATES**

BY

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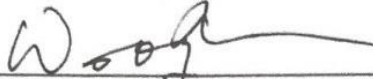
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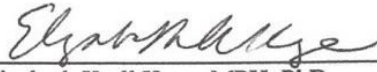
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DEDICATION

I would like to dedicate this work to my supportive husband Ahmed, my wonderful daughter Yasmina, my family and my in laws. Without their patience, assistance, understanding, and most of all love, the completion of this work would not have been possible.

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Eman Behbehani

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ABSTRACT

OBJECTIVES: This study has three aims: 1) to determine the trends and prevalence of dental fluorosis and caries among persons aged 6-19; 2) to examine the association between dental fluorosis and caries among persons of the same age group; and 3) to investigate the influence of dental fluorosis and caries on oral health-related quality of life (OHRQoL) among people aged 16-49 in the United States.

METHODS: The data from the National Health and Nutrition Examination Survey (NHANES) 1999-2004 and 2011-2012 were analyzed. For aims 1) and 2), individuals aged 6-19 years, who completed the home interview and oral health examination were included (n=9,493, n=2,411, respectively). For aim 3, the data from NHANES 2003-2004 were analyzed including only people aged 16-49, who completed the home interview and both conditions examination (n=3,035). The reason behind age restriction is that people aged 16-49 were targeted to answer OHRQoL questions. Dental fluorosis was measured by Dean's Index (6-categories of severity), where classification was based on the two teeth most affected by fluorosis. Dental caries experience was measured by DMFS score

(overall caries experience and untreated decay). OHRQoL was calculated as sum of 7 items out of the 14 items NHANES Oral Health Impact Profile (OHIP-14). OHRQoL score can range 6-28 (lower score indicates better oral health). Other covariates were socio-demographic characteristics, self-perceived mouth/teeth condition (1-item), and previous dental visit (time and reason). Bivariate and multivariate analyses were conducted with caries and OHRQoL as outcomes. All analyses were weighted and adjusted for the complex design of the NHANES survey, using SAS 9.3 survey procedures.

RESULTS: For aim 1, dental fluorosis prevalence among persons aged 6-19 was increasing (37% vs. 57%) from 1999-2004 to 2011-2012. There was a significant increase in caries experience and a significant decrease in untreated tooth decay from 1999-2004 to 2011-2012 among persons aged 6-19. For aim 2, the crude association between the severity of fluorosis and DMFS was significantly inversely proportional except for the moderate/severe categories of fluorosis where the relationship was linear. For aim 3, the bivariate all teeth analysis showed that OHRQoL was significantly decreased with higher level of fluorosis severity (p-value=0.05). Severity of fluorosis was significantly inversely associated with DMFS score (β -coefficient=-4.8, p-value <0.0001). The lower DMFS scores explain the better perception of oral health (lower OHRQoL scores) in higher fluorosis severity groups. However, after controlling of DMFS and covariates in a multiple regression model, fluorosis severity was not significantly associated with lower OHRQoL score.

CONCLUSIONS: Overall, the findings of this study suggest that the prevalence of dental fluorosis is increasing while untreated decay is decreasing among persons aged 6-19. The results demonstrated a clear inverse relationship between dental fluorosis and caries. The findings also suggest that the benefit of fluorides outweighs the esthetic impact of fluorosis among the U.S children and adolescents.

KEYWORDS: NHANES, Dental fluorosis, Dental caries, OHRQoL.

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GLOSSARY

Dental Fluorosis: refers to changes in the appearance of tooth enamel that are caused by long-term ingestion of fluoride during the time teeth are forming. The criteria for classifying and scoring dental fluorosis are modified from the system described by Dean in 1942. Each tooth is examined and assigned to one of six categories according to its degree of dental fluorosis. For analysis, classification of a person is based on the two teeth most affected by fluorosis. If the two teeth are not equally affected, the classification given to the person is the score for the less involved tooth.

Dental Caries: a process of demineralization of tooth enamel, leading to destruction of enamel and dentin, with cavitation of the tooth. Decayed and infected teeth can be the source of other infections throughout the body, and decayed or missing teeth can interfere with proper chewing of food, leading to nutritional deficiencies or disorders of digestion. Also called tooth decay.

Oral Health Related Quality of Life (OHRQoL): a multidimensional construct that includes a subjective evaluation of the individual's oral health, functional well-being, emotional well-being, expectations and satisfaction with care, and sense of self. The OHRQoL instrument in NHANES, which is composed of 7-questions, is the shortest version of the Oral Health Impact Profile (OHIP-14), which is composed of 7-questions. Responses to questions were made on a 5-point ordinal scale ranging from "never", "hardly ever", "occasionally", "fairly often" and "often".

CHAPTER I

INTRODUCTION

Dental fluorosis is a change in the mineralization of dental hard tissues caused by long-term ingestion of fluoride during the early periods of tooth development (first 8 years of life for most permanent teeth) (*Fejerskov et al., 1990*). Although the use of fluoride in various modalities has been important in the prevention and control of dental caries, it also introduces the risk for dental fluorosis (*Pendrys et al., 1989; Pendrys et al., 1990*). The milder forms typically are not noticeable; however, more severe levels might be objectionable for cosmetic and functional reasons. Reported risk factors for the more severe forms of fluorosis include drinking water with high natural fluoride levels, dietary fluoride supplements, ingestion of fluoride toothpaste, and having multiple sources of ingested fluoride (*Mascarenhas, 2000*).

In 1942, H. Trendley Dean has documented the prevalence of dental fluorosis for most of the US states. He found that dental fluorosis prevalence in its milder forms was 11% among adolescents. Later on, by analyzing the data from 1986-87 National Survey of US School Children, it was found that adolescent's aged 12-15 had 21.3% dental fluorosis experience, in its milder forms. In 1999-2004, dental fluorosis prevalence has increased to 37.1% using NHANES data. The National Research Council (NRC) of the National Academics of Science identified severe dental fluorosis as an adverse health effect because of enamel pitting that affects its protective function. The NRC focused on the adverse effects from naturally occurring fluoride in drinking water at 2-4 mg/L;

however, they did not examine the benefits and risks that might occur at lower fluoride concentrations typically used in community water systems, at 0.7-1.2 mg/L (*NRC, 2006*).

Dental caries or cavities are caused by a breakdown of tooth enamel that is caused by bacteria, which breakdown foods and produce acid that destroys tooth enamel and results in tooth decay (*Selwitz et al., 2007*). Although dental caries are largely preventable, they remain the most common chronic disease of children and adolescents. Tooth decay is four times more common than asthma among adolescents aged 14 to 17 years (*CDC, 2006*). Dental caries can be prevented by drinking fluoridated water, brushing with fluoridated toothpaste, flossing and eating nutritious and balanced meals with limited snacking. Systematic reviews related to fluoride concluded that community water fluoridation (CWF) is effective in decreasing dental caries prevalence and severity (*Yeung CA, 2008; Community Preventive Services Task Force, 2014*). The beneficial effects of CWF in reducing dental caries were still present even after the introduction of other fluoride delivery modalities such as fluoride toothpaste (*Slade et al., 2013*). In the United States, the prevalence of decayed, missing, or filled teeth decreased from 57.3% in 12- to 15-year-old children in 1988-1994 (*Beltran-Aguilar et al., 2005*) 1988 to 50.6% in 1999-2004.

To investigate the lowest fluoride level at which dental caries is inhibited, Dean conducted the “21 cities study” on children aged 12-14 with lifetime residence in communities with various but stable mean F levels in their domestic water (*CDC, 1999*). The results of this ecological study showed that dental caries experience in different

communities dropped sharply as F concentration rose toward 1 ppm then leveled off; whereas, dental fluorosis experience rose sharply above 1 ppm F concentration (*Dean HT, 1938*). Accordingly, the optimal level of fluoride in drinking water was set to 1 ppm, in which drinking water was the main source for fluoride delivery. Later, due to the introduction of other sources of fluoride, the optimal level of fluoride in drinking water was reconsidered. It was found that the sharpest caries decline was associated with water fluoride levels between 0-0.7 ppm with little additional decline between 0.7-1.2 ppm. However, dental fluorosis increased with water fluoride levels between 0.7-1.2 with the sharpest increase when fluoride is >1.2 ppm. A suitable trade-off between caries and fluorosis occurred at 0.7 ppm. (*Heller et al., 1997*).

Oral health-related quality of life (OHRQoL) is “a multidimensional construct that includes a subjective evaluation of the individual’s oral health, functional well-being, emotional well-being, expectations and satisfaction with care, and sense of self” (*DHHS, 2000*). In regard to the relationship between dental caries and OHRQoL, a number of studies concluded that dental caries have negative impact on OHRQoL (*Kramer et al., 2013; Abanto et al., 2014, Ramos-Jorge et al., 2014*). Few studies were conducted to investigate the impact of dental fluorosis on OHRQoL, which showed mixed results. Do and Spencer found that mild fluorosis had a positive impact on Australian child and parental OHRQoL because it is associated with a decrease in caries experience (*Do and Spencer, 2007*). However, in North Carolina, a study showed that schoolchildren’s dental fluorosis has no impact on OHRQoL (*Onoriobe et al., 2014*).

Exposure to the optimal level of fluorides leads to reduction of caries experience, which in turn will reduce negative impacts of dental caries on OHRQoL (*Ramos-Jorge et al., 2014*). Conversely, there is potential for exposure to excessive fluorides to cause dental fluorosis, which may affect esthetics and cause negative impacts on OHRQoL (*Aguilar-Diaz, et al., 2011*). However, individuals' self-perception of dental esthetics is subjective, hence the relationship between dental fluorosis and OHRQoL is not straightforward.

Our study aims to describe the trend and prevalence of dental fluorosis and dental caries among children and adolescents in the United States, because there is no update upon the prevalence and severity of both conditions since 1999-2004. Also, we examined the association between dental fluorosis and dental caries among children and adolescents according to the modern context of fluoride intake. Finally, this study will determine the impact of dental fluorosis concurrently with dental caries on OHRQoL, in which we will consider the effects of anterior teeth fluorosis on OHRQoL.

CHAPTER II

LITERATURE REVIEW

I. THE TREND AND PREVALENCE OF DENTAL FLUOROSIS AND CARIES

i. DENTAL FLUOROSIS

In 1930s and early 1940s, Dean was the first to discover dental fluorosis in the United States by his famous classic studies. He established a direct association between fluoride in the drinking water and changes in the tooth enamel, which was named later as enamel fluorosis (*Dean, 1942*). In 1980, the National Institute of Dental and Craniofacial Research (NIDCR) visited seven of Northern Illinois naturally fluoridated communities and according to a 5-year follow-up plan, those communities were revisited in 1985 and 1990 (*Heifetz et al., 1988; Selwitz et al., 1995*). Relating age to fluorosis and tooth calcification, the NIDCR report in 1990 concluded that there was an increase in age-standardized fluorosis in optimally fluoridated areas over 1980-1985; however, this increase did not continue in 1985-1990.

Since the time of Dean, it is clear that the prevalence of dental fluorosis has increased (*Clark, 1994; Szpuner and Burt, 1987*). In 1986-1987, the National Survey of Dental Caries in the US School Children reported that 22.3% of children had mostly mild to very mild dental fluorosis, ranging by age from 18.5% in 17-year-olds to 25.8% in 9-years-olds (*Brunelle, 1989*). Having higher prevalence among the younger age group suggests that the prevalence might still be increasing. A report regarding the prevalence and severity of dental fluorosis in the United States in 1999-2004 was released in 2010 by

the NCHS. Among persons aged 16-49, 16% had very mild fluorosis, 4.8% had mild fluorosis, 2% had moderate fluorosis and less than 1% had severe fluorosis. In addition, the prevalence of dental fluorosis remains higher among younger persons when compared to older ones. Among adolescents aged 12-15, 41% had dental fluorosis, however, among adults aged 40-49, only 9% had dental fluorosis. Moreover, children aged 12-15 years-olds in 1999-2004 had higher prevalence of dental fluorosis when compared with the same aged children in 1986-1987 (*Beltran-Aguilar et al., 2010*).

ii. DENTAL CARIES

For the most of the 20th century, the prevalence of dental caries was higher in developed countries than the developing countries and the most obvious reason is diet. The high level consumption of sugars was associated with wealthier countries; on the other hand, people in poorer countries were living by hunting and farming, both of which provide diet with low carbohydrates (*Burt and Eklund, 2005*). This traditional pattern has been reversed by the late 20th century; a marked reduction in caries experience was found in developed countries and a sharp rising in caries experience was found in developing countries. In the United States, the World War II surveys showed that the most severe caries experience was seen in recruits from New England, the Pacific Northwest, and the Great Lakes area; on the other hand, the lower caries experience was found in the south, southwest, and the mountain states (*Ludwig and Bibby, 1969*). These changes in caries experience are not unique to the United States. For example, in Britain, despite the overall reduction in dental caries, oral health is still poorer in Scotland and Northern

England than in Southern England (*Pitts and Evans, 1997*). Some of these changes have been obscured by the spread of water fluoridation and other caries preventive measures.

Globally, according to the World Health Organization (WHO), 60-90% of school children and the vast majority of adults have dental caries, which lead to pain and discomfort (*WHO, 2015*). In the 1980s, reports from local surveys in the United States suggested that the average prevalence and severity of dental caries among children was declining (*Bryan et al., 1982; Glass, 1981; Stookey et al., 1985*). Similar reports were released about other high-income countries indicating the widespread decrease in dental caries experience (*Hugoson et al., 1980; Hunter, 1979*). While percentages of untreated dental caries have declined from 1971-1974 (25.0% in children ages 2-5 and 54.7% in children ages 6-19), data for the most recent time period still show high levels of untreated cavities: 19.5% in children ages 2-5 and 22.9% in children ages 6-19 (*CDC, 2010*).

The main caries problem is the disparities in the disease experience and treatment between different socioeconomic and racial-ethnic groups. In 2009-2010, national survey data showed that untreated dental caries among children varied by race/ethnicity and federal poverty level. About one in four children living below 100% of the federal poverty level had untreated dental caries (*Dye and Thornton-Evans, 2012*). This will result in pain, school absences and poorer school performance (*Detty and Oza-Frank, 2014*).

II. THE ASSOCIATION BETWEEN DENTAL FLUOROSIS AND CARIES

With the aims to determine the lowest fluoride levels at which a balance between dental fluorosis and dental caries exists. Dr. Trendly Dean conducted the “21 cities study” in which clinical examinations of children aged 12-14 years with lifetime residence in 8 suburban Chicago communities were performed (*CDC, 1999*). The project expanded by adding 13 additional cities in Illinois, Colorado, Ohio and Indiana (*CDC, 1999*). Dean found that caries experience dropped sharply when fluoride concentration in the drinking water reach up to 1.0 ppm F and it levels off above that; however, in higher fluoride concentrations where individuals are seen with severe fluorosis, caries experience increased (*Dean HT, 1938*). In this study, individuals’ variation in water drinking was ignored. Moreover, the optimal level of fluoride in drinking water was 1 ppm according to Dean when drinking water was the only source of fluoride intake. However, other fluoride delivery modalities, such as fluoride toothpastes, and fluoride supplements have been discovered that enhanced the fluoride intake of people who are living in non-fluoridated communities by fluoride diffusion and dilution from fluoridated communities “halo-effect” (*Carey, 2014*). Using the data from 1986-87 National Survey of US school children, it was found that the sharpest decline in caries experience (measured by dfs: decayed and filled teeth in primary dentition; and DMFS: decayed, missing due to caries, filled teeth in permanent dentition) were associated with increase in water fluoride levels between 0-0.7 ppm F, with little additional decline between 0.7 and 1.2 ppm F. In addition, the highest fluorosis prevalence was 41.4% for children who consumed >1.2 ppm F water (*Heller et al., 1997*).

Fluoride effects on caries prevention have been well documented, as has its role in dental fluorosis (*Lalumandier et al., 1995; Levy et al., 2000 Franzman et al., 2004*). Therefore, attempts to update the optimal level of fluoride intake have been carried out considering the effect of various fluoride products such as topical fluorides. By analyzing the data on fluoride ingestion from Iowa fluoride study in children aged 5-9 years, it has been shown that the mean daily fluoride intake for children with no caries history or fluorosis experience was at or below 0.05 mg/kg of body weight; however, those with caries history had generally lower intakes and those with fluorosis had slightly higher intakes (*Warren JJ et al., 2009*). Consequently, due to the overlap between caries and fluorosis in fluoride intake and variability in individuals' intake, the decision to recommend the optimal fluoride intake is problematic.

In the literature, studies investigating the prevalence of dental fluorosis in relation to the level of dental caries are mostly ecological studies in which the units of analysis are groups rather than individuals (*S.M. Szpunar et al., 1988; S.R. Grobler et al., 2001*). The underlying problem in ecological studies is that groups are not entirely homogenous in regard to the exposure and covariates, which will introduce "ecological fallacy"; this means that associations on the group level will differ from associations between the same variables measured at the individual level in the same population. These studies concluded that dental caries is inversely proportional to dental fluorosis in fluoridated communities. However, it is unknown whether all subjects in a fluoridated community have the same exposure to fluoride from drinking water that will result in reduction of

dental caries. Therefore, examining the association between dental fluorosis and caries at the individual level will give more controlled estimates.

In our study, we hypothesized that dental fluorosis has an inverse relationship with dental caries. Also, we will consider individual level factors such as demographics, income level and dental behavior aspects, in which specific groups can be targeted with fluorides and community water fluoridation campaigns. Moreover, due to the increase in fluoride sources and the amount of its ingestion, we hypothesized that dental fluorosis is increasing; hence, this study will investigate how much risk of dental fluorosis is tolerable in order to prevent dental caries.

THE MECHANISM OF FLUORIDE ACTION

The action of fluoride in preventing caries is multifactorial. There are three major mechanisms by which fluoride inhibits the development of dental caries; two mechanisms are post-eruptive, which are promotion of re-mineralization and inhibition of de-mineralization of early carious lesions and inhibition of glycolysis, the process by which bacteria metabolize fermentable carbohydrates. The third mechanism is some reduction in enamel solubility in acid by pre-eruptive incorporation of fluoride into the hydroxyapatite crystal. Fluoride in dental plaque and saliva works primarily through topical re-mineralization of tooth surfaces (*Featherstone, 1999*).

Excess fluoride available to the enamel during maturation disrupts mineralization and results in excessive retention of enamel proteins (*Badwen et al., 1995*). Although high fluoride concentrations might affect enamel at all tooth developmental stages, enamel in

early pre-eruptive maturation is the most sensitive to the effects of fluoride (*Evans and Stamm, 1991*). In addition, dental fluorosis is a dose-response condition, the higher fluoride intake during the critical period of tooth development, the more severe the fluorosis.

III. THE OHRQoL ASPECTS OF DENTAL FLUOROSIS AND CARIES

i. DENTAL FLUOROSIS WITH OHRQOL

The psychosocial consequences of dental fluorosis including perceptions, aesthetic concerns, and the effect on OHRQoL, have been reported in the literature over the past years. Some studies demonstrated that people with mild forms of dental fluorosis have significant dissatisfaction over their appearance (*Levy et al., 2002*). In a review that was done from 1985 to 2009, it was found that severe fluorosis has negative impacts on OHRQoL; however, very mild and mild fluorosis has either no effect or positive impacts on OHRQoL (*Chankanka et al., 2010; McGrady MG, et al., 2012*). In addition, it was found that severe dental fluorosis could make it difficult to interact and form relationships, which will lead to loneliness, depression and other undesirable social behaviors (*Spencer et al., 1996*). Do and Spencer (2007) evaluated the association of dental caries and fluorosis with children's global self rating of oral health and measures of OHRQoL reported by the children themselves and their parents. The included children aged 8-13 and they were examined for dental caries, dental fluorosis, and occlusal traits. The fluorosis examination was based on the Thylstrup-Fejerskov (TF) score on maxillary central incisors only. Children answered age-specific Child Perception Questionnaire (CPQ) for 8-10 or 11-14 years old groups and their parents answered a Parental Perception Questionnaire (PPQ). The results showed that dental caries had negative impact while mild fluorosis had positive impact on both child and parental OHRQoL. Another study that was conducted in Mexico on schoolchildren aged 8-10 years living in

a high-fluoridated community concluded that both caries and fluorosis in their severe forms had negative impact on CPQ for 8-10 years (*Aguilar-Diaz, et al., 2011*).

ii. DENTAL CARIES WITH OHRQOL

Oral disease is a global problem, but it is often perceived as low priority because it is rarely life threatening. However, after the tragic death of the 12 years old Deamonte Driver in 2007 from untreated tooth infection, people's perception regarding oral health have changed. Oral disease can have a significant impact on the psychosocial aspects of an individual's life. Oral health problems can affect an individual's quality of life by impairing physical and social functioning, as well as their self-esteem (*Chen and Hunter, 1996*). In Brazil and China, a number of studies were conducted to explore the association between dental caries and OHRQoL (*Kramer et al., 2013; Li et al., 2014*), which concluded that caries experience in schoolchildren is negatively associated with OHRQoL. In regard to the impact of visible dental caries on social judgments, it was found that poor dental condition is highly correlated with perceived poor social performance and intellectual ability; in addition, a more central position of caries is more predictive to poor social judgment than just the presence of visible dental caries (*Somani et al., 2010*). In Sweden, a study was conducted to explore the effect of caries on OHRQoL among adolescents aged 19 years, which concluded that caries prevalence and incidence in Sweden is too low to affect OHRQoL, therefore the usefulness of OHRQoL measures in caries prevention is questioned specifically at that region (*Oscarson N, 2007*). There are few studies that simultaneously consider the association of dental

fluorosis and caries with OHRQoL to determine both the risks and benefits of fluoride exposures (*Onoriobe et al., 2014; Robinson et al., 2005*). Those studies concluded that caries experience affects OHRQoL negatively, while fluorosis has little impact.

In summary, there is no update upon the prevalence of dental fluorosis and caries among children and adolescents in the United States since 1999-2004. In addition, due to the increase in fluoride delivery sources and the amount of its ingestion, dental fluorosis is expected to increase; hence, this study will investigate the association between dental fluorosis and caries IN the current context of fluoride intakes and how much risk of dental fluorosis increase is tolerable in order to prevent dental caries. Furthermore, this study will determine the impact of dental fluorosis and caries concurrently, in which both conditions are controlling for each other, on OHRQoL among adolescents and adults.

OBJECTIVES

- I. Describe the trend and prevalence of dental fluorosis and dental caries among persons aged 6-19 years in the United States (1999-2004 vs. 2011-2012).
- II. Determine the association between dental fluorosis and dental caries at the individual level in relation to different factors among persons aged 6-19 years in the United States (1999-2004 vs. 2011-2012).
- III. Determine the Oral Health-related Quality of Life (OHRQoL) aspects of dental fluorosis and dental caries among people aged 16-49 years in the United States (2003-2004).

CHAPTER III

METHODS

DATA SOURCE

Data were obtained from the National Health and Nutrition Examination Survey (NHANES) from 1999-2002, 2003-2004 and 2011-2012. NHANES is a nationally representative data for the civilian non-institutionalized population in the 50 states of the U.S. and the District of Columbia. Subjects are interviewed in their homes and they have completed the health examination component of the survey in mobile examination centers (MECs) (*NHANES, 2013-2014*).

a. OVERVIEW

NHANES is a program of studies designed to assess the health and nutritional status of adults and children in the United States. The survey consists of two major components, which are interviews and physical examinations. It is a major program of the National Center for Health Statistics (NCHS), which is part of the Centers for Disease Control and Prevention (CDC) and has the responsibility for producing vital and health statistics for the Nation. The NHANES program began in the early 1960s and has been conducted as a series of surveys focusing on different population groups or health topics. In 1999, the survey became a continuous program that has a changing focus on a variety of health and nutrition measurements to meet emerging needs. The survey examines a nationally representative sample of about 5,000 persons each year. These persons are located in counties across the country, 15 of which are visited each year (*NHANES, 2013-2014*)

The NHANES interview includes demographic, socioeconomic, dietary, and health-related questions. The examination component consists of medical, dental, and physiological measurements, as well as laboratory tests administered by highly trained medical personnel. Findings from this survey are used to determine the prevalence of major diseases and risk factors for diseases. Information is used to assess nutritional status and its association with health promotion and disease prevention. NHANES findings are also the basis for national standards for such measurements as height, weight, and blood pressure. Data from this survey will be used in epidemiological studies and health sciences research, which help develop sound public health policy, direct and design health programs and services, and expand the health knowledge for the Nation (*NHANES Overview, 2013-2014*).

b. SURVEY CONTENT

The sample for the survey is selected to represent the U.S. population of all ages. NHANES over samples persons 60 and older, African Americans, and Hispanics to produce reliable statistics. All participants visit the physician. Dietary interviews and body measurements are included for everyone. All but the very young have a blood sample taken and will have a dental screening. Depending upon the age of the participant, the rest of the examination includes tests and procedures to assess the various aspects of health (*NHANES: Plan and Operations, 2013*)

c. SURVEY OPERATIONS

Health interviews are conducted in respondents' homes. Health measurements are performed in specially designed and equipped mobile centers, which travel to locations throughout the country. The study team consists of a physician, medical and health technicians, as well as dietary and health interviewers, and most of the staff can speak both English and Spanish. An advanced computer system using high-end servers, desktop PCs, and wide-area networking collect and process all of the NHANES data, nearly eliminating the need for paper forms and manual coding operations. This system allows interviewers to use notebook computers with electronic pens. The staff at the mobile center can automatically transmit data into databases through such devices as digital scales. Touch-sensitive computer screens let respondents enter their own responses to certain sensitive questions in complete privacy. Survey information is available to NCHS staff within 24 hours of collection, which enhances the capability of collecting quality data and increases the speed with which results are released to the public.

In each location, local health and government officials are notified of the upcoming survey. Households in the study area receive a letter from the NCHS Director to introduce the survey. NHANES is designed to facilitate and encourage participation. Transportation is provided to and from the mobile center if necessary. Participants receive compensation and a report of medical findings is given to each participant. All information collected in the survey is kept strictly confidential. Privacy is protected by public laws (*NHANES: Plan and Operations, 2013*)

d. RESPONSE RATES (*NHANES: Response Rates*)

- **NHANES 1999-2000**, there were 12,160 persons selected for the sample, 9,965 (82%) of those were interviewed and 9,282 (76%) were examined in the mobile examination centers (MEC).
- **NHANES 2001-2002**, there were 13,156 persons selected for the sample, 11,039 (84%) of those were interviewed and 10,477 (80%) were examined in the MEC.
- **NHANES 2003-2004**, there were 12,761 persons selected for the sample, 10,122 (79%) of those were interviewed and 9,643 (76%) were examined in the MEC.
- **NHANES 2011-2012**, there were 13,431 persons selected for the sample, 9,756 (72.6%) of those were interviewed and 9,338 (69.5%) were examined in the mobile examination centers (MEC).

IRB APPROVAL

This research is exempted from the Institutional Review Board (IRB) at Henry M. Goldman School of Dental Medicine – Boston University, because the data in the National Health and Nutrition Examination Survey (NHANES) is publicly available and subjects are anonymous, i.e. no names, addresses or any personal identifiers are used. The CDC removed all other information that might potentially breach the confidentiality of participants before the datasets were released for public use. Therefore, the subjects are protected from the risk of break of confidentiality. This study is exempted since there are no identifiable data.

SAMPLE AND DATA COLLECTION

a. OBJECTIVE I & OBJECTIVE II

To determine the trends and prevalence of dental fluorosis and dental caries over the years, and to examine the association between dental fluorosis and dental caries at the individual level, NHANES 1999-2004 and NHANES 2011-2012 datasets were used in the analysis. To compare the two cycles, we selected people aged 6-19 years. The reason for including only people aged 6-19 is because dental fluorosis examination was done only for that age group in NHANES 2011-2012, and in order to make comparisons between NHANES 1999-2004 and NHANES 2011-2012 it was decided to include only the common ages between the two cycles. Therefore, final datasets include 9,493 (1999-2004) and 2,411 (2011-2012) 6-19 year old children and adolescents who completed the home interview and oral health examination for dental fluorosis and dental caries.

b. OBJECTIVE III

To explore the relationship between OHRQoL according to dental fluorosis and dental caries, NHANES 2003-2004 cycle was used, since it is the only cycle that provides information on both OHRQoL and dental fluorosis variables.

For this analysis, people aged 16-49 years were selected. The reason behind including participants' aged 16-49 is because people at this age group were both examined for dental fluorosis and answered OHRQoL questions (OHIP-14 version) in NHANES 2003-2004. So, the final dataset include 3,035 (2003-2004) 16-49 years participants who completed the home interview and oral health examination for dental fluorosis and dental caries.

VARIABLES OF INTEREST

a. DENTAL FLUOROSIS

The criteria for classifying and scoring dental fluorosis are modified from the system described by Dean in 1942. Each tooth is examined and assigned to one of six categories according to its degree of dental fluorosis. For analysis, classification of a person is based on the two teeth most affected by fluorosis. If the two teeth are not equally affected, the classification given to the person is the score for the less involved tooth. For the purpose of the dental examination in this study, each tooth is classified. The modified criteria and the corresponding scores described by Dean are provided in the table below.

| Dean's (Score ^a) | Classification | Criteria | Operational Definition |
|------------------------------|----------------|---|---|
| Normal - (0) | | The enamel presents the usual translucent semi-vitriform type of structures. The surface is smooth, glossy, and usually of a pale creamy white color. | Criteria that do not meet definitions below. |
| Questionable- (0.5) | | The enamel shows slight aberrations from the translucency of normal enamel, ranging from a few white flecks to occasional white spots. This classification is utilized in those instances where a definite diagnosis of the very mild form of fluorosis is not warranted and a classification of "normal" is not justified. | Occasional white spots. |
| Very Mild - (1) | | Small, opaque, paper white areas scattered irregularly over the enamel but involving less than 25 percent of the total surface area. Included in this category are teeth that show no more than 1-2 mm of white opacity at the cusp tips of posterior teeth or incisal edges of anterior teeth. | Paper white areas, scattered over 25 percent of the tooth surface or less. One should be confident of the diagnosis of fluorosis based on the pattern in the mouth and the type of lesions. The lesions are bilaterally symmetrical and the margin of lesion blends or is not clearly defined. Otherwise call it questionable. |
| Mild - (2) | | The white opaque areas are more extensive but involve less than 50% of the total surface area. | Greater than 25 percent, but less than 50 percent of any tooth surface is affected. |
| Moderate - (3) | | 50 percent or greater of the tooth surface area is affected. All enamel surfaces of the teeth are affected, and surfaces subject to attrition show marked wear. Brown stain is frequently a disfiguring feature. | 50 percent or greater of the tooth is affected. All visible surfaces (occlusal, buccal, and lingual of posterior teeth; or facial and lingual surfaces of anterior teeth) must be involved. Posterior teeth typically show attrition because fluorosed surfaces wear easily. The area that has undergone attrition is considered as fluorosed for scoring purposes. If there is marked attrition, this has to be considered when determining the extent of involvement (consider this area as fluorosed). Anterior teeth out of occlusion may not show attrition. |
| Severe - (4) | | All enamel surfaces are affected. The diagnostic sign required for this classification, is discrete or confluent pitting of the enamel. With marked confluent pitting, the tooth often presents a corroded-like appearance. Brown stains of intact enamel are often present. | A fluorosed tooth with discrete or confluent pitting. General form of the tooth may be affected. |

b. DENTAL CARIES

Each subject included receives the coronal caries assessment [Decayed, Missing, and Filled Surface Index (DMFS)]. All permanent teeth except the third molars are assessed. Each quadrant is dried with air and examined with a surface reflecting mirror and a No. 23 explorer. In addition to the DMFS score, which denotes the overall caries experience, untreated tooth decay was also measured. It represented the “Decayed” part of the DMFS that will give a better indicator for the burden of the disease.

c. ORAL HEALTH RELATED-QUALITY OF LIFE (OHRQOL)

The OHRQoL instrument in NHANES is the shortest version of the Oral Health Impact Profile (OHIP-14). This short OHRQoL instrument is composed of seven questions, one question from each of the following theoretical domains: functional limitation, physical disability, social disability, and handicap; two questions from the physical pain domain and one question from both psychological disability and psychological discomfort domains. Responses to questions were made on a 5-point ordinal scale ranging from “never”, “hardly ever”, “occasionally”, “fairly often” and “often”.

d. COVARIATES

Covariates in the analysis include age (6-49 years), gender (male vs. female), race/ethnicity (non-Hispanic white, non-Hispanic black, Hispanic and other Hispanic/other races), education (less than high, high school, more than high school), income, which is measured as Federal Poverty Level (FPL) that is categorized into three categories: Low (<100 FPL), Medium (100%-199% FPL) and high (>=200 FPL), dental

behavior (time of last dental visit and reason), and oral health perception of mouth and teeth (excellent, good, poor).

STATISTICAL ANALYSIS

All analyses are conducted using Survey Procedures in SAS 9.3 (*SAS Institute Inc., Cary, NC, USA*), and take into account the weighted and clustered sampling design of NHANES. Descriptive statistics for the population is calculated. *Categorical variables* are tested with the *Pearson chi-square test* and *continuous variables* are tested with the *t-test*. Bivariate analysis is performed to determine the effect of covariates on each variable of interest. Also, multiple regressions were performed to examine the effects of potential confounders. The significance level will be defined at 2-tailed alpha equal to or less than 0.05.

a. OBJECTIVE I

- I. Describe the trend and prevalence of dental fluorosis and dental caries among persons aged 6-19 years in the United States (1999-2004 vs. 2011-2012).
- II. Determine the association between dental fluorosis and dental caries at the individual level in relation to different factors among persons aged 6-19 years in the United States (1999-2004, vs. 2011-2012).
- III. Determine the Oral Health-related Quality of Life (OHRQoL) aspects of dental fluorosis and dental caries among people aged 16-49 years in the United States (2003-2004).

The datasets from NHANES 1999-2004 and NHANES 2011-2012 were analyzed. To know the trends in the prevalence of dental fluorosis among different age groups, weighted bivariate analysis was performed for both NHANES waves. In addition, the distribution of dental fluorosis according to the following variables: gender, race/ethnicity, education, income, oral health perception, time since last dental visit and reason was determined. Moreover, we want to know the difference in the prevalence of dental caries, which is measured by DMFS score, from NHANES 1999-2004 to NHANES 2011-2012. Weighted bivariate analysis was performed to determine the prevalence of dental caries among different age groups. In addition, the prevalence of dental caries and the prevalence of untreated tooth decay in permanent teeth were calculated according to selected characteristics. Then, a comparison between the mean DMFS from NHANES 1999-2004 to NHANES 2011-2012 was reported according to different age groups. Finally, the distribution of the mean dental caries experience by socio-demographics, oral health perception and dental behavior in NHANES 1999-2004 compared to NHANES 2011-2012 was calculated.

b. OBJECTIVE II

Determine the association between dental fluorosis and dental caries in relation to different factors among persons aged 6-19 years at the individual level in the United States between 1999-2004, and 2011-2012.

To investigate the relationship between dental caries and dental fluorosis at the individual level, weighted bivariate and multivariate models were developed. First, the crude

association between the two conditions from NHANES 1999-2004 and NHANES 2011-12 was reported. In addition, the crude association between dental caries and dental fluorosis among different age groups was determined from the two NHANES waves. Then, a multivariable linear regression model was developed to test the association between dental caries, as dependent variable and dental fluorosis adjusting for covariates. Finally, two weighted multivariable regression models were created among people aged 8-9 years using NHANES 1999-2004 to evaluate whether an exposure to fluoride in the early years of life has caries preventive effect on permanent teeth.

c. OBJECTIVE III

Determine the Oral Health-related Quality of Life (OHRQoL) aspects of dental fluorosis and dental caries among people aged 16-49 years in the United States (2003-2004).

To investigate the association between dental fluorosis and OHRQoL, NHANES 2003-2004 wave was used because it is the only wave that includes information on both variables. The independent variables were dental fluorosis experience according to Dean's Index, socio-demographic factors (age, gender, race/ethnicity, income), and dental factors (DMFS, self-perceived mouth/teeth condition and previous dental visit time and reason). The dependent variable was the sum of scores of the following seven OHIP questions:

1) How often during last year have you had painful aching anywhere in your mouth?

- 2) How often during last year have you felt life in general was less satisfying because of problems with your teeth, mouth, or dentures?
- 3) How often during last year have you had difficulty doing your usual jobs or attending school because of problems with teeth, mouth, or dentures?
- 4) How often during last year has your sense of taste been affected by problems with your teeth, mouth, or dentures?
- 5) How often during last year have you avoided particular food because of problems with your teeth, mouth, or dentures?
- 6) How often during last year have you found it uncomfortable to eat any food because of problems with your teeth, mouth, or dentures?
- 7) How often during last year have you been self-conscious or embarrassed because of your teeth, mouth, or dentures?

The aggregated OHRQoL scores ranged from 7 to 28, with a lower score indicating better oral health related quality of life. In addition, the responses from lower end of the scale, which are very often and fairly often, were combined because the response rate was too low. Accordingly, the primary outcome related to OHRQoL is continuous variable that is calculated by the summation of all seven questions for an overall OHRQoL score. The secondary outcome related to OHRQoL is binary variable (no/yes) that was created by combining the two upper responses (never and hardly ever) and the two lower responses (occasionally and often), respectively.

The statistical analysis was conducted at four levels. First, weighted univariate analysis was performed to calculate the distribution of the original items related to OHRQoL.

Then, to examine the associations between dental fluorosis, dental caries and OHRQoL, weighted bivariate analysis was used for all teeth, anterior teeth and posterior teeth. After that, a weighted multivariable linear regression model was created for the continuous OHRQoL outcome to predict its association with dental fluorosis adjusted for socio-demographics (age, gender, race/ethnicity, education and income), dental caries, and dental behavior factors (time since last dental visit and reason). Moreover, to investigate the effect of dental fluorosis on OHRQoL item-by-item, weighted multivariable logistic regression models were created for each item, where the outcome of interest was “yes”, which is the combination of “occasionally” and “often” responses, and the main predictor was dental fluorosis, controlling for age, gender, race/ethnicity, education, income and dental caries. Stratification analysis, by gender and poverty status, was performed to determine the relationship between OHRQoL with dental fluorosis and dental carries. Finally, since dental fluorosis is an esthetic problem, an anterior teeth only analysis was done to determine the effect of dental fluorosis on OHRQoL. A weighted multivariable linear regression model and weighted multivariable logistic regression models were re-created to investigate the effect of dental fluorosis on anterior teeth on OHRQoL (continuous and item by item, respectively).

CHAPTER IV

RESULTS

I. OBJECTIVE I: TRENDS IN THE PREVALENCE OF DENTAL FLUOROSIS AND DENTAL CARIES

a. TRENDS IN DENTAL FLUOROSIS

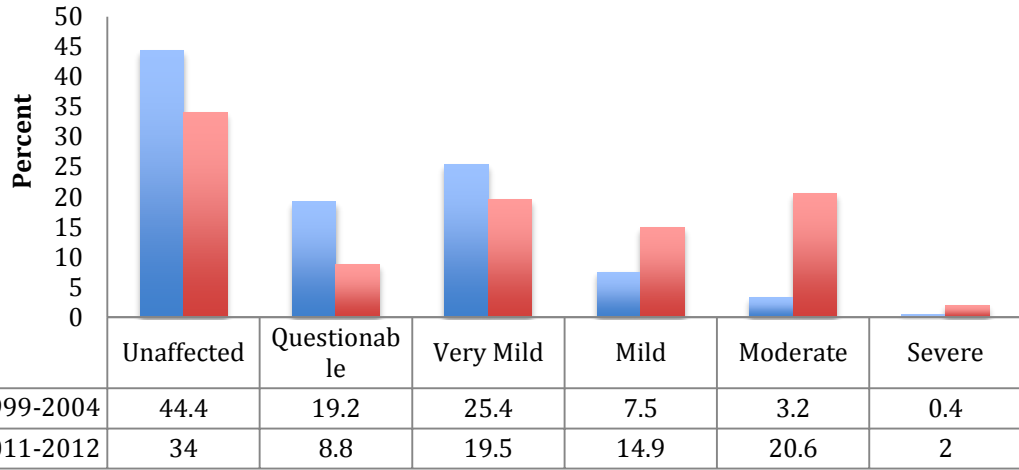
i. OVERALL SAMPLE (6-19 years)

In NHANES 1999-2004, among persons aged 6-19, 25% had very mild fluorosis, 8% had mild fluorosis, 3% had moderate fluorosis and 1% had severe fluorosis. For the remaining of persons with this age group, 44% were unaffected by dental fluorosis and 19% were classified as having questionable dental fluorosis.

However, in NHANES 2011-2012, among persons aged 6-19, 19% had very mild fluorosis, 15% had mild fluorosis, 21% had moderate fluorosis and 2% had severe fluorosis. For the remaining of persons with this age group, 34% were unaffected by dental fluorosis and 9% were classified as having questionable dental fluorosis.

So, regarding the trend of dental fluorosis prevalence among persons aged 6-19, dental fluorosis prevalence is increasing for most of fluorosis categories (mild, moderate and severe) and the number of unaffected persons and those having questionable fluorosis is decreasing.

Figure 1. Percent Distribution of Dental Fluorosis among Persons Aged 6-19: NHANES 1999-2004 vs. 2011-2012

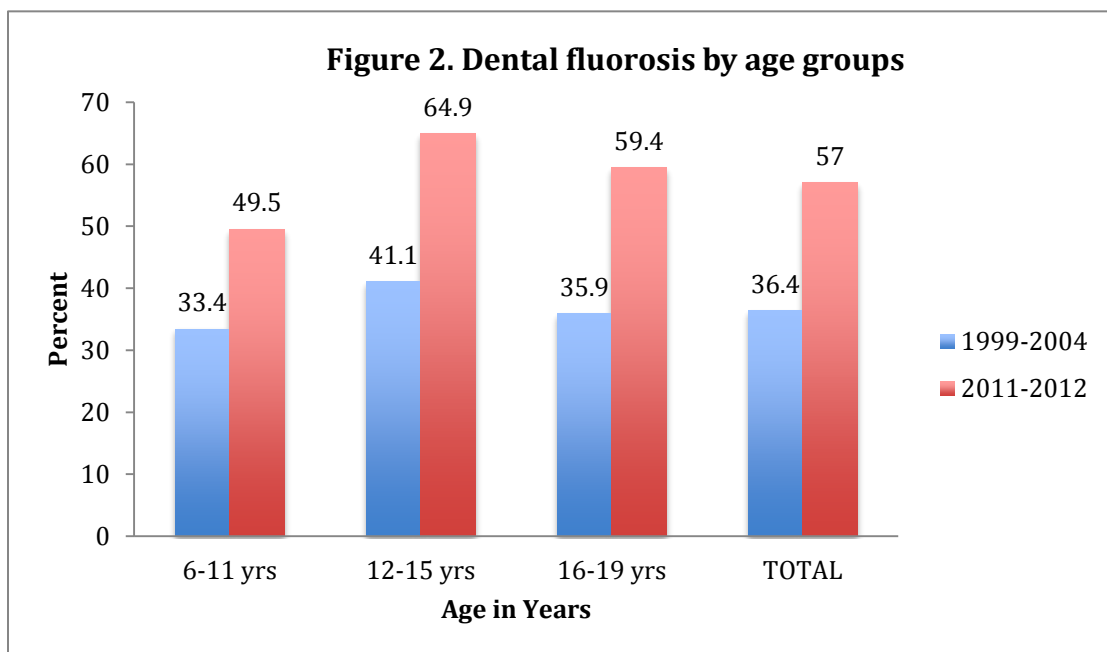


NOTES: Dental fluorosis is defined as having very mild, mild, moderate, or severe forms and is based on the most affected tooth according to Dean's Fluorosis Index.

ii. BY AGE GROUPS

In NHANES 1999-2004, adolescents' aged 12–15 had the highest prevalence of dental fluorosis (41.1%). The prevalence of dental fluorosis among children aged 6–11 (33.4%) was lower than the prevalence among those aged 12–15 (41.1%).

Similarly, in NHANES 2011-2012, adolescents' aged 12–15 had the highest prevalence of dental fluorosis (64.9%). The prevalence of dental fluorosis among children aged 6–11 (49.5%) was lower than the prevalence among those aged 12–15 (64.9%).

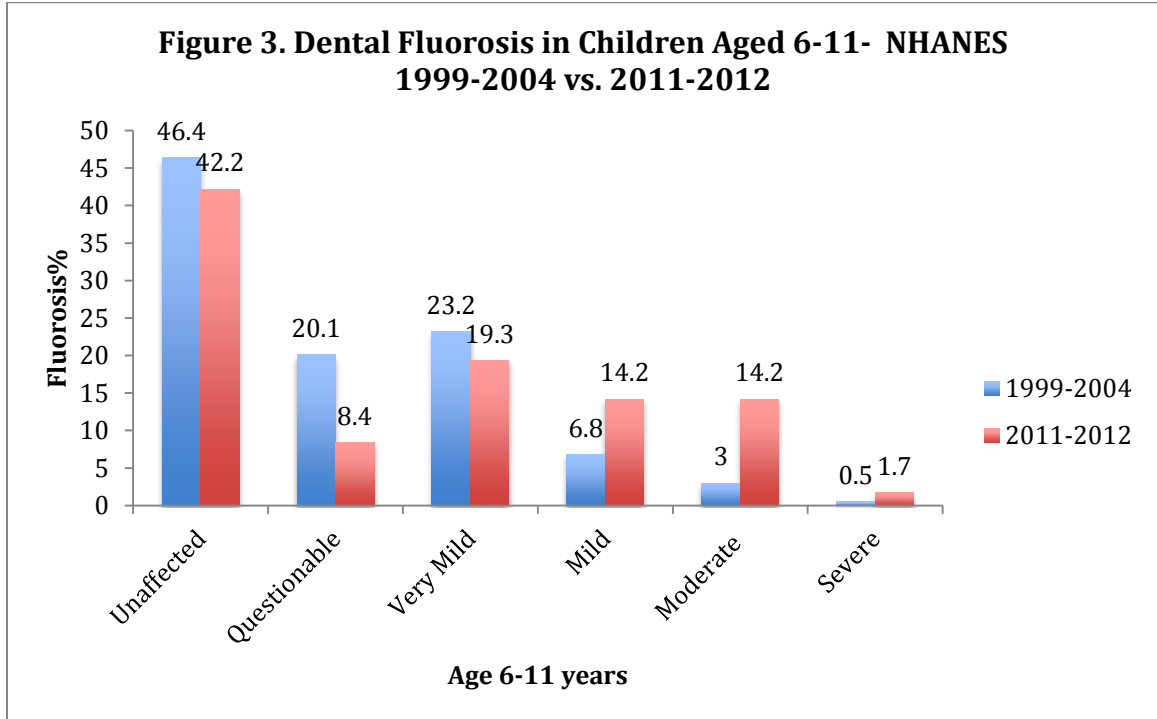


NOTES: Dental fluorosis is defined as having very mild, mild, moderate, or severe forms and is based on the most affected tooth according to Dean's Fluorosis Index. Percentages are weighted age row%. P-value <0.0001

iii. DENTAL FLUOROSIS SEVERITY BY AGE GROUPS

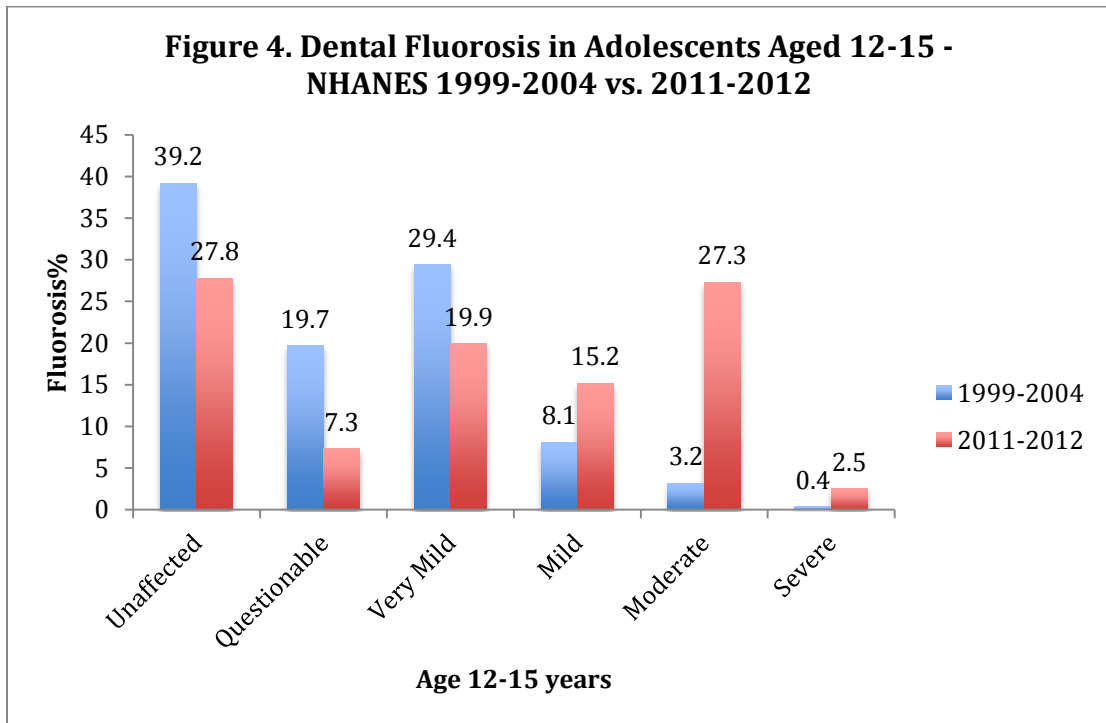
- **Change in dental fluorosis distribution among children aged 6-11 participating in NHANES 1999-2004 and 2011-2012.**

In 1999-2004, 33.4% of children aged 6-11 had dental fluorosis whereas in 2011-2012, 49.5% of children aged 6-11 had dental fluorosis. The prevalence of very mild fluorosis decreased from 23.2% to 19.3% and mild fluorosis increased from 6.8% to 14.2%. The prevalence of moderate fluorosis increased from 3% to 14.2% and severe fluorosis also increased from 0.5 to 1.7%.



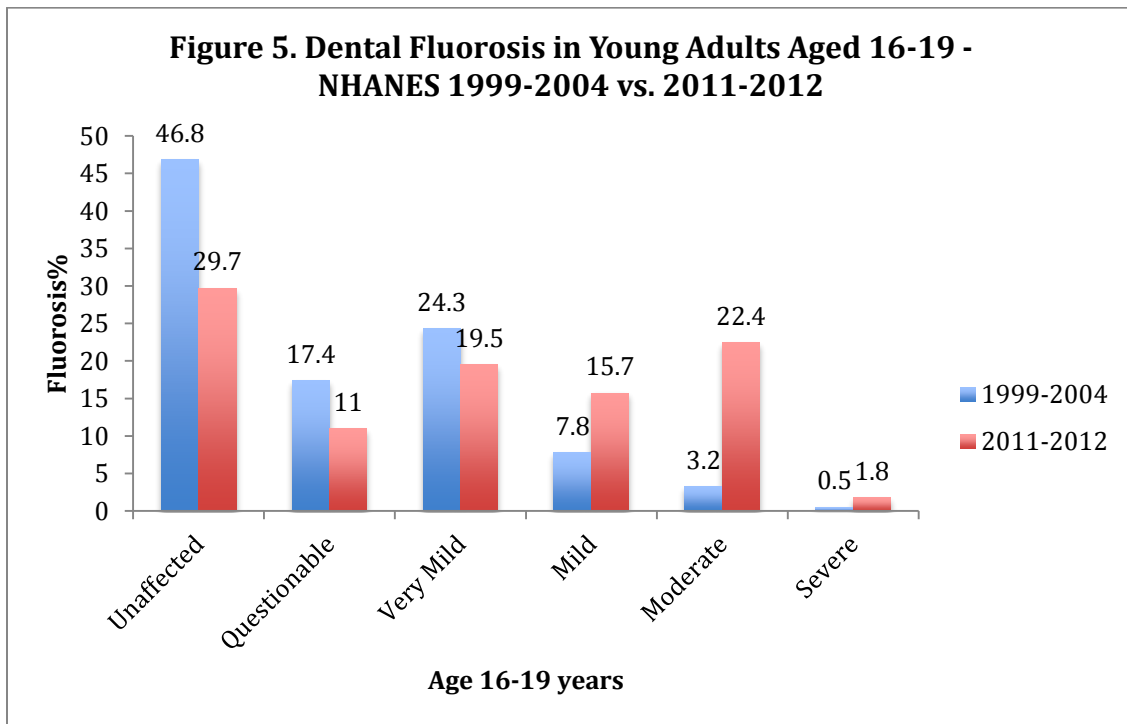
- **Change in dental fluorosis distribution among adolescents aged 12-15 participating in NHANES 1999-2004 and 2011-2012.**

In 1999-2004, 41.1% of adolescents' aged 12–15 had dental fluorosis, whereas in 2011-2012, 64.9% of adolescents' aged 12–15 had dental fluorosis. The prevalence of very mild fluorosis decreased from 29.4% to 19.9% and mild fluorosis increased from 8.1% to 15.2%. The prevalence of moderate fluorosis increased from 3.2% to 27.3% and severe fluorosis also increased from 0.4 to 2.5%.



- **Change in dental fluorosis distribution among adults aged 16-19 participating in NHANES 1999-2004 and 2011-2012.**

In 1999-2004, 35.9% of young adults aged 16-19 had dental fluorosis, whereas in 2011-2012, 59.4% of young adults aged 16-19 had dental fluorosis. The prevalence of very mild fluorosis decreased from 24.3% to 19.5% and mild fluorosis increased from 7.8% to 15.7%. The prevalence of moderate fluorosis increased from 3.2% to 22.4% and severe fluorosis also increased from 0.5 to 1.8%.



**iv. BIVARIATE TABLE ON THE DISTRIBUTION OF DENTAL
FLUOROSIS BY SELECTED FACTORS**

Table 1 shows the distribution of dental fluorosis in NHANES 1999-2004 compared to NHANES 2011-2012 according to socio-demographic factors, oral health perception and dental behavior. In NHANES 1999-2004, dental fluorosis was higher in people aged 12-15 (41.1%) compared to those aged 6-11 (33.4%) or 16-19 (35.9%). In addition, females (37.2%), non-Hispanic Blacks (51.0%), and those who lived in low Federal Poverty Level (37.6%) had the highest dental fluorosis experience. Moreover, among people aged 6-19, those who visited the dentist in <12 months (35.9%) and those who had dental treatment (36.0%) had lower dental fluorosis experience. In NHANES 2011-2012, similar patterns of dental fluorosis distribution, among people aged 6-19, were observed. However, those who lived in high Federal Poverty Level (59.2%) had the highest dental fluorosis experience. Regarding oral health perception, people who had poor perception about their mouth and teeth had more dental fluorosis compared to people who had excellent or good perception in both cycles. Overall, dental fluorosis experience increased among people aged 6-19 from NHANES 1999-2004 to NHANES 2011-2012.

Table 1: Distribution of dental fluorosis among individuals aged 6-19 by demographics, OH perception and dental behavior, from 1999-2004 compared to 2011-2012 in the United States

| Variables | 1999-2004 | | 2011-2012 | | Difference% |
|------------------------------|-----------|-------------|-----------|------------|-------------|
| | Fluorosis | | Fluorosis | | |
| | n | Weighted %* | n | Weighted % | |
| Age | | | | | |
| 6-11 | 1075 | 33.4 | 585 | 49.5 | + 16.1 |
| 12-15 | 1445 | 41.1 | 377 | 64.9 | + 23.8 |
| 16-19 | 1234 | 35.9 | 355 | 59.4 | + 23.5 |
| Gender | | | | | |
| Males | 1856 | 35.7 | 670 | 55.9 | + 20.2 |
| Females | 1898 | 37.2 | 647 | 58.3 | + 21.1 |
| Race/Ethnicity | | | | | |
| Non-Hispanic Whites | 760 | 31.7 | 305 | 58.4 | + 26.7 |
| Non-Hispanic Blacks | 1500 | 51.0 | 428 | 62.3 | + 11.3 |
| Mexican American | 1202 | 41.3 | 223 | 51.4 | + 10.1 |
| Other races | 292 | 37.1 | 361 | 52.9 | + 15.8 |
| Federal Poverty Level | | | | | |
| Low (<100% FPL) | 1197 | 37.6 | 429 | 55.9 | + 18.3 |
| Medium (100%-199% FPL) | 959 | 37.1 | 312 | 55.4 | + 18.3 |
| High (>=200% FPL) | 1304 | 35.7 | 462 | 59.2 | + 23.5 |
| OH perception | | | | | |
| Excellent | 828 | 31.0 | 645 | 56.3 | + 25.3 |
| Good | 1804 | 35.3 | 641 | 58.2 | + 22.9 |
| Poor | 135 | 35.2 | 31 | 54.4 | + 19.2 |

| | | | | | |
|--------------------------------------|------|------|------|------|--------|
| Time since last dental visit | | | | | |
| < 12 months | 2468 | 35.9 | 1060 | 57.1 | + 21.2 |
| 1-5 years | 866 | 37.5 | 217 | 59.2 | + 21.7 |
| >5 years or never | 405 | 39.2 | 37 | 44.2 | + 5 |
| Reason for last dental visit | | | | | |
| Checkup, examination, or cleaning | 2669 | 36.5 | 1053 | 57.6 | + 21.1 |
| Treatment | 717 | 36.0 | 223 | 55.5 | +19.5 |
| Other | 95 | 36.6 | 18 | 64.0 | + 27.4 |

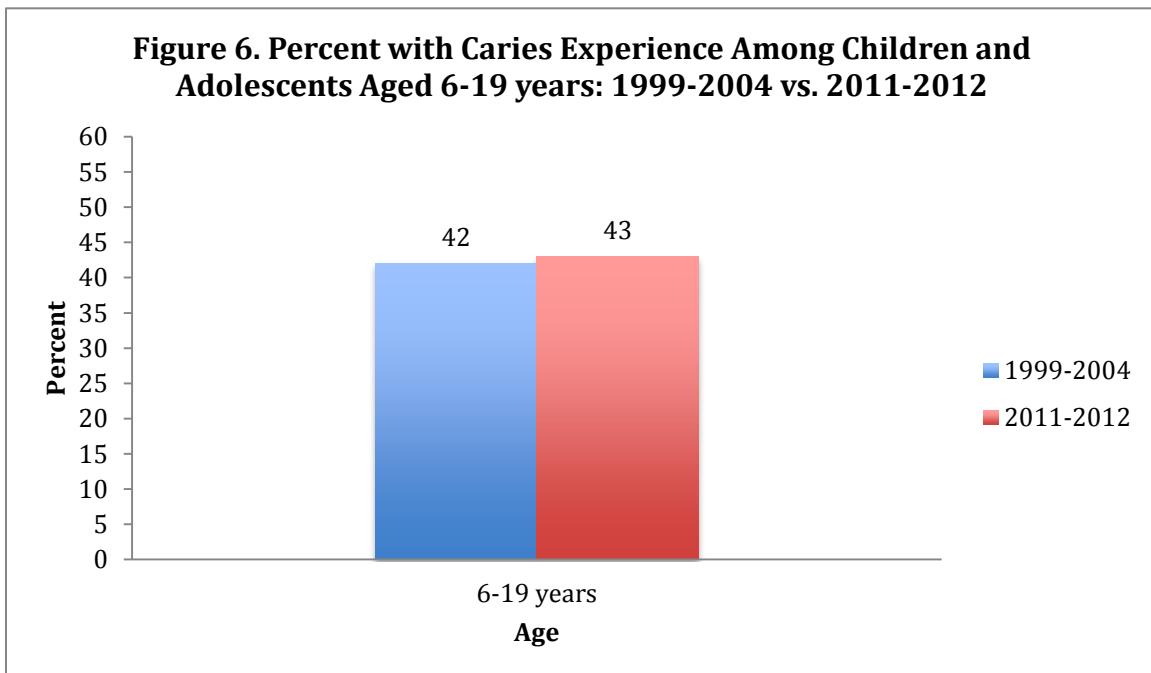
NOTES: Dental fluorosis is defined as having very mild, mild, moderate, or severe forms and is based on Dean's Fluorosis Index. Questionable category is excluded. *Percentages are weighted row%.

a. TRENDS OF DENTAL CARIES

i. DENTAL CARIES EXPERIENCE

1. OVERALL SAMPLE (6-19 years)

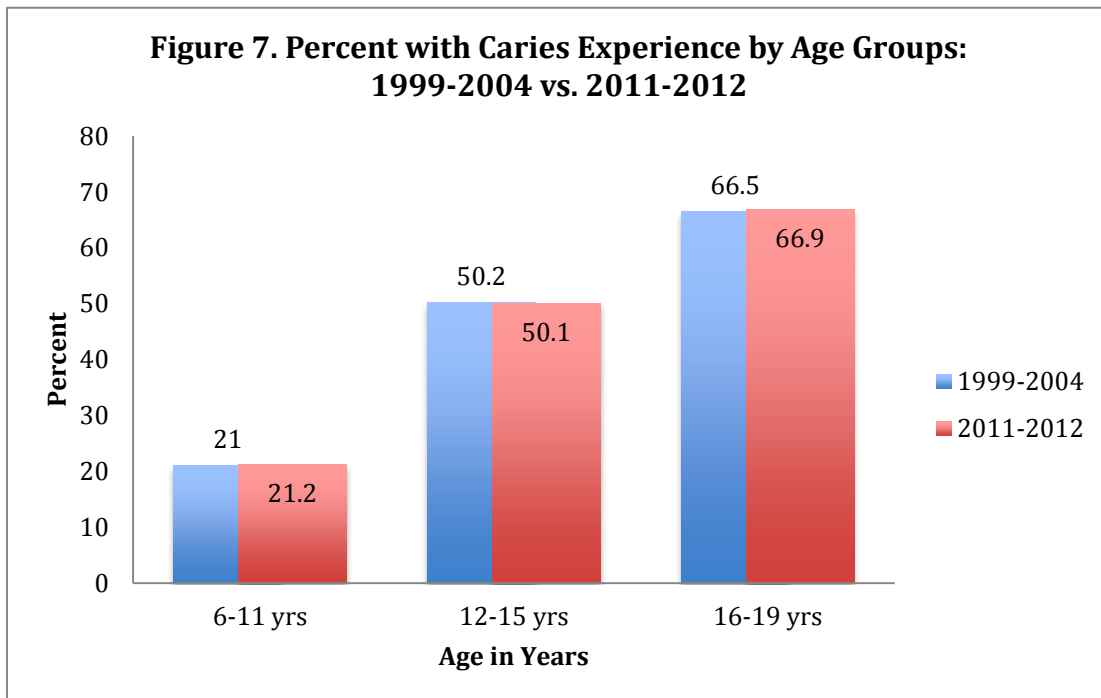
Caries experience is one measure to monitor trends in dental caries. It includes both treated (filled) and untreated caries. Figure 6 demonstrates a comparison in caries experience among children and adolescents aged 6-19 in the United States from 1999-2004 to 2011-2012. Among children and adolescents aged 6-19, 42% had experienced caries in 1999-2004. The percentage of caries experience among persons of the same age group was almost the same (43%) in 2011-2012. Thus, dental caries experience has not been changed among children and adolescents in the United States from 1999-2004 to 2011-2012.



*Caries experience: treated (filled) and untreated dental caries.

2. BY AGE GROUPS

Figure 7 shows the percent with caries experience (DMFS>0) among children and adolescents aged 6-19 years by age groups. Overall, caries experience had not changed across the three different age groups (6-11, 12-15, and 16-19 years) from 1999-2004 to 2011-2012. Young adults aged 16-19 had the highest caries experience in their permanent teeth compared to other age groups. On the other hand, children aged 6-11 had the lowest caries experience compared to other age groups. This can be explained by an incomplete set of permanent teeth among children aged 6-11 compared adolescents aged 12-15 and young adults aged 16-19.



*Caries experience: treated (filled) and untreated dental caries. Differences in the percentage of caries experience among different age groups for each cycle is statistically significant (P-value <0.0001).

3. BIVARIATE TABLE ON THE DISTRIBUTION OF CARIES
EXPERIENCE (DMFS>0) BY SELECTED FACTORS

Table 2 shows the prevalence of dental caries, which includes treated and untreated dental caries, in permanent teeth among people aged 6-19 in NHANES 1999-2004 compared to NHANES 2011-2012. In NHANES 1999-2004, dental caries experience was significantly high among people aged 16-19 (66.5%), females (45.0%), Mexican Americans (48.0%), and those who lived in low Federal Poverty Level (49.2%). Moreover, people with poor oral health perception had significantly higher dental caries experience (59%), compared to those with excellent (33.1%) or good (50.8%) perception. Regarding dental behavior, people who visited the dentist in <12 months (42.8%) and those who had dental treatment (59.3%) had significantly higher dental caries experience compared to those who visited the dentist in >5 years or never (25.6%) and those who had dental check-up, examination or cleaning in the dental office (38.9%), respectively. In NHANES 2011-2012, similar trends, in dental caries experience, was found among people aged 6-19. However, males (43.6%) had higher dental caries experience, compared to females (42.1%). Regarding oral health perception, people with poor oral health perception (62.1%) had higher dental caries experience compared to those with excellent (35.5%) or good (51.8%) perception. In regard to dental behavior, those who visited the dentist in 1-5 years (47.6%) and those who had dental treatment (57.9%) had higher prevalence of dental caries, compared to those who visited the dentist in <12 months (42.0%) or >5 years or never (40.3%) and those who had dental check-up, examination or cleaning in the dental office (39.4%), respectively. Overall, dental caries

experience increased from NHANES 1999-2004 compared to NHANES 2011-2012, among people aged 6-19. However, it is decreased among people aged 12-15 (-0.1%), females (-2.9%), those with more than high school education (-3.5%), people living in low (-0.1%) and high (-1.8%) Federal Poverty Level, those who visited the dentist in <12 months (-0.8%) and those who had dental treatment (-1.4%).

| Table2: Caries experience in permanent teeth, according to selected characteristics: USA, NHANES 1999-2004 compared to 2011-2012 | | | | | |
|---|------------------|-----------------------|------------------|-----------------------|--------------------|
| Variables | 1999-2004 | | 2011-2012 | | Difference% |
| | Percent% | Standard Error | Percent% | Standard Error | |
| Age | | | | | |
| 6-11 | 21.0 | 1.1 | 21.2 | 1.6 | + 0.2 |
| 12-15 | 50.2 | 1.3 | 50.1 | 3.7 | - 0.1 |
| 16-19 | 66.5 | 1.4 | 66.9 | 2.3 | + 0.4 |
| Gender | | | | | |
| Males | 39.1 | 1.1 | 43.6 | 2.4 | + 4.5 |
| Females | 45.0 | 1.2 | 42.1 | 2.1 | - 2.9 |
| Race/ Ethnicity | | | | | |
| Non-Hispanic Whites | 40.6 | 1.5 | 40.6 | 2.6 | 0 |
| Non-Hispanic Blacks | 37.6 | 1.5 | 45.1 | 2.5 | + 7.5 |
| Mexican American | 48.0 | 1.3 | 50.1 | 2.6 | + 2.1 |
| Other races | 47.7 | 2.6 | 41.7 | 2.5 | + 6.0 |
| Federal Poverty Level | | | | | |
| Low (<100% FPL) | 49.2 | 1.6 | 49.1 | 2.5 | - 0.1 |
| Medium (100%-199% FPL) | 44.1 | 1.9 | 47.6 | 4.3 | + 3.5 |
| High (>=200% FPL) | 37.1 | 1.3 | 35.3 | 3.0 | - 1.8 |
| Oral Health Perception | | | | | |
| Excellent | 33.1 | 1.4 | 35.5 | 1.9 | + 2.4 |
| Good | 50.8 | 1.4 | 51.8 | 1.6 | + 1.0 |
| Poor | 59.0 | 4.4 | 62.1 | 8.6 | + 3.1 |

| | | | | | |
|---------------------------------------|------|-----|------|-----|--------|
| Time since last dental visit | | | | | |
| <12 months | 42.8 | 1.0 | 42.0 | 2.0 | - 0.8 |
| 1-5 years | 44.4 | 2.0 | 47.6 | 2.9 | + 3.2 |
| >5 years, never | 25.6 | 2.2 | 40.3 | 9.8 | + 14.7 |
| Reason of last dental visit | | | | | |
| Check-up, examination, or cleaning | 38.9 | 1.1 | 39.4 | 2.1 | + 0.5 |
| Treatment | 59.3 | 1.5 | 57.9 | 2.9 | - 1.4 |
| Other | 44.3 | 4.6 | 55.1 | 9.1 | + 10.8 |

- Dental caries: treated (F) and untreated (D) dental caries

* 1999-2004: All variables were statistically significant in relation to prevalence of caries.

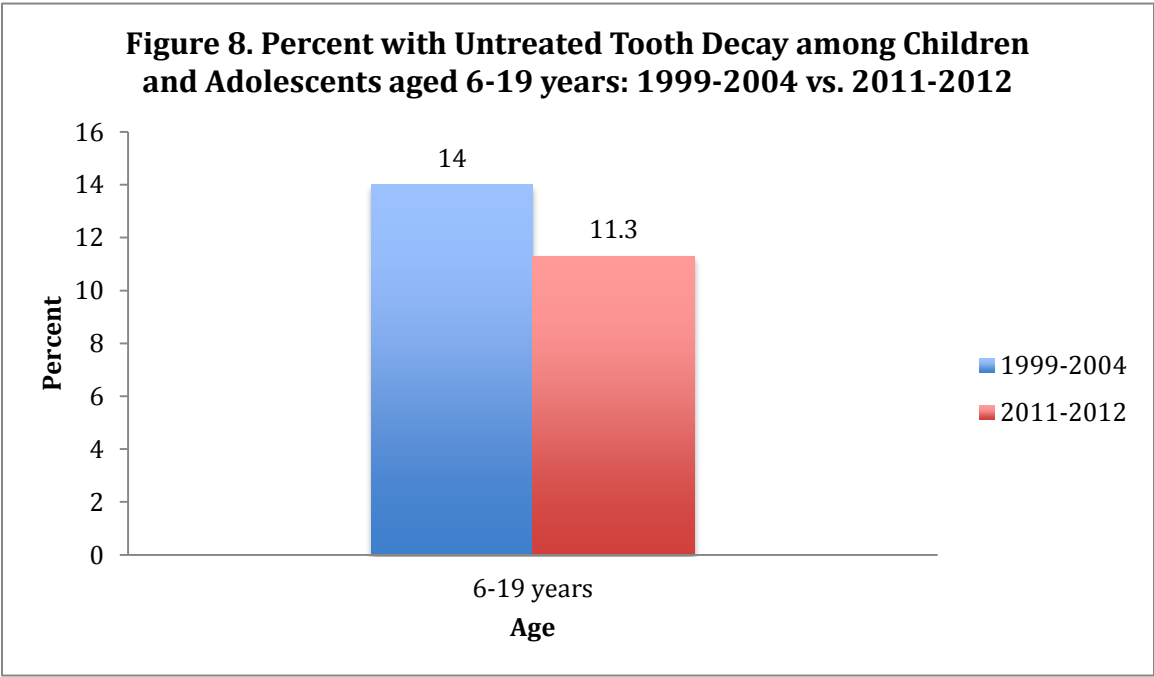
**2011-2012: All variables, except gender and time since last dental visit, were statistically significant.

- The sign of the difference% denotes the direction of effect (+: increase, -: decrease).

ii. UNTREATED TOOTH DECAY

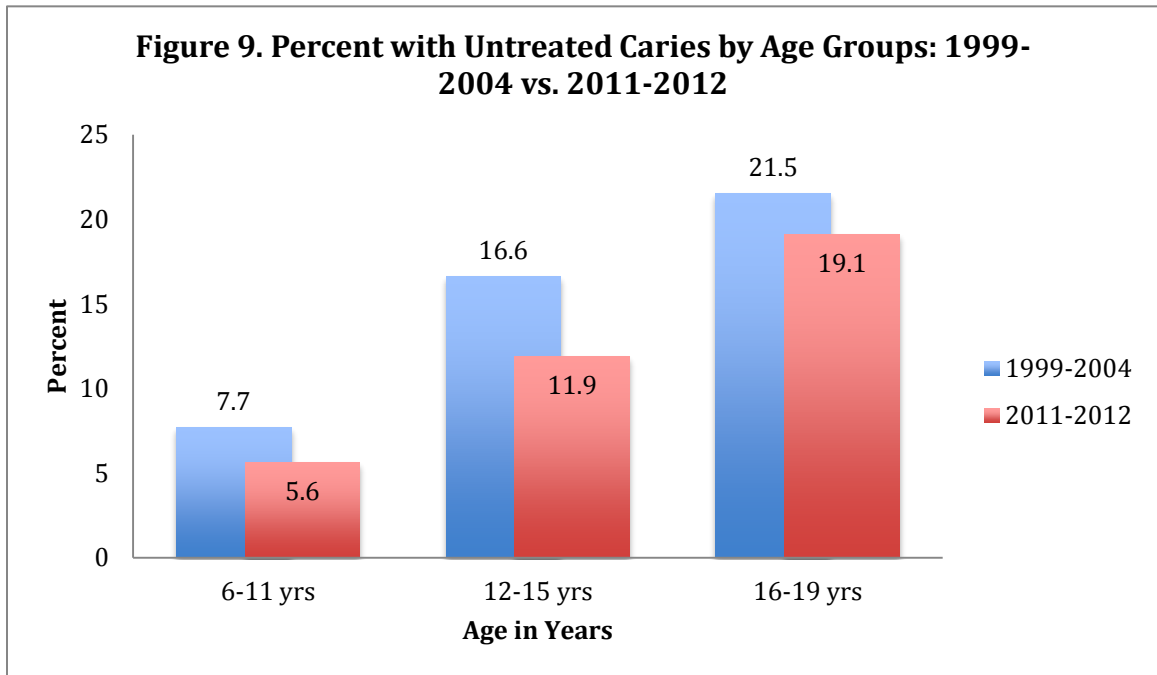
1. OVERALL SAMPLE (6-19 years)

The percent with untreated tooth decay is another measure to monitor trends in dental caries. It accounts for the decayed part only of the DMFS score. Overall, the percent with untreated tooth decay in permanent teeth among children and adolescents aged 6-19 had decreased from 1999-2004 (14%) to 2011-2012 (11.3%).



2. BY AGE GROUPS

Figure 9 shows the percent with untreated tooth decay among children and adolescents aged 6-19 years by age groups. Overall, untreated tooth decay had decreased across the three different age groups (6-11, 12-15, and 16-19 years) from 1999-2004 to 2011-2012. The highest decrease in the percentage of untreated tooth decay from 1999-2004 to 2011-2012 was among adolescents aged 12-15 (16.6% vs. 11.9%, respectively) compared to other age groups. This can be explained by an incomplete set of permanent teeth among children aged 6-11 compared adolescents aged 12-15 and young adults aged 16-19.



*Differences in the percentage of untreated tooth decay among age groups for each cycle are statistically significant (P-value <0.0001).

3. BIVARIATE TABLE ON THE DISTRIBUTION OF UNTREATED TOOTH DECAY BY SELECTED FACTORS

Table 3 indicates the prevalence of untreated tooth decay, which denotes the decayed aspect of DMFS score, in permanent teeth among people aged 6-19 in NHANES 1999-2004 compared to NHANES 2011-2012. In NHANES 1999-2004, the prevalence of untreated tooth decay was significantly higher among people aged 16-19 (21.5%) compared to those aged 6-11 (7.7%) or 12-15 (16.6%). Males and females had similar percentages (14.1% vs. 14.2%, respectively), thus, the relationship between gender and untreated tooth decay was not statistically significant. In regard to other socio-demographic factors: Mexican Americans (20.9%) and those who are living below the Federal Poverty Level (20.1%) had significantly higher untreated tooth decay. In addition, people who had poor perception about their mouth and teeth (37.5%) had significantly higher untreated tooth decay percentage compared to those with excellent (7.5%) or good (17.7%) perception. Regarding dental behavior, those who visited the dentist in <12 months (10.9%) and those who had dental check-up, examination or cleaning in the dental office (10.9%) had significantly lower prevalence of untreated tooth decay, compared to those who visited the dentist in 1-5 years (23.6%) and those who had dental treatment (25.7%), respectively. Similarly, in NHANES 2011-2012, young adults aged 16-19 (19.1%), Mexican Americans (15.8%) and persons living below the Federal Poverty Level (16.9%) had lower percentage of untreated tooth decay. The difference in the prevalence of untreated tooth decay in males and females is not statistically significant (12.3% vs. 10.3%, respectively). For oral health perception, those

with poor perception (10.1%) had significantly higher untreated tooth decay compared to those with excellent (1.0%) or good (1.4%) perception. Finally, regarding dental behavior in relation to the prevalence of untreated tooth decay, similar trend was found as in NHANES 1999-2004. Overall, the percentage of untreated tooth decay in permanent teeth among people aged 6-19 is decreasing from NHANES 1999-2004 compared to NHANES 2011-2012, with few exceptions where it is increasing [among those with poor oral health perception (+5.2%), those who had their last dental visit in > 5 years or never (+9.2%) and those who had other than check-up, examination, cleaning or treatment in the dental office (+8.7%)].

| Table3: Prevalence of untreated tooth decay in permanent teeth, according to selected characteristics: USA, NHANES 1999-2004 compared to 2011-2012 | | | | | |
|---|------------------|-----------------------|------------------|-----------------------|--------------------|
| Variables | 1999-2004 | | 2011-2012 | | Difference% |
| | Percent% | Standard Error | Percent% | Standard Error | |
| Age | | | | | |
| 6-11 | 7.7 | 0.9 | 5.6 | 0.9 | - 2.1 |
| 12-15 | 16.6 | 1.1 | 11.9 | 1.4 | - 4.7 |
| 16-19 | 21.5 | 1.5 | 19.1 | 2.2 | - 2.4 |
| Gender | | | | | |
| Males | 14.1 | 0.9 | 12.3 | 1.2 | - 1.8 |
| Females | 14.2 | 0.9 | 10.3 | 1.4 | - 3.9 |
| Race/ Ethnicity | | | | | |
| Non-Hispanic Whites | 11.2 | 1.2 | 9.6 | 1.0 | - 1.6 |
| Non-Hispanic Blacks | 17.6 | 1.1 | 15.3 | 2.0 | - 2.3 |
| Mexican American | 20.9 | 1.0 | 15.8 | 2.4 | - 5.1 |
| Other races | 17.6 | 2.1 | 9.5 | 1.7 | - 8.1 |
| Federal Poverty Level | | | | | |
| Low (<100% FPL) | 20.1 | 1.3 | 16.9 | 1.3 | - 3.2 |
| Medium (100%-199% FPL) | 19.3 | 1.5 | 12.9 | 2.6 | - 6.4 |
| High (>=200% FPL) | 8.5 | 0.8 | 6.3 | 1.2 | - 2.2 |
| Oral Health Perception | | | | | |
| Excellent | 7.5 | 0.6 | 6.4 | 1.0 | - 1.1 |
| Good | 17.7 | 1.1 | 16.3 | 1.4 | - 1.4 |
| Poor | 37.5 | 4.8 | 42.7 | 10.1 | + 5.2 |
| Time since last dental visit | | | | | |
| <12 months | 10.9 | 0.8 | 8.3 | 0.9 | - 2.6 |
| 1-5 years | 23.6 | 1.5 | 23.6 | 2.9 | 0 |
| >5 years, never | 22.3 | 2.1 | 31.5 | 9.1 | + 9.2 |
| Reason of last dental visit | | | | | |
| Checkup, examination or cleaning | 10.9 | 0.7 | 9.3 | 0.8 | - 1.6 |
| Treatment | 25.7 | 1.9 | 17.9 | 1.6 | - 7.8 |
| Other | 13.8 | 2.8 | 22.5 | 11.7 | + 8.7 |

* 1999-2004: all variables, except gender, were statistically significant in relation to prevalence of untreated decay.

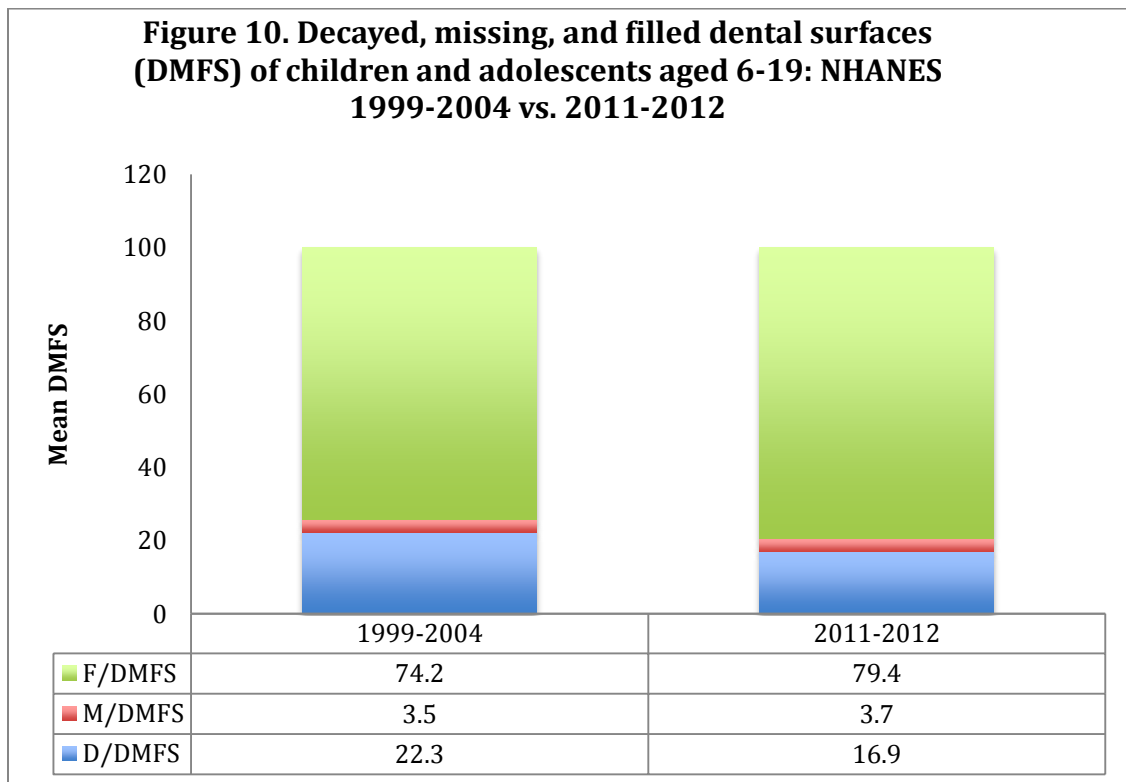
** 2011-2012: All variables, except gender, were statistically significant.

- The sign of the difference% denotes the direction of effect (+: increase, -: decrease).

iii. % COMPOSITION OF DMFS

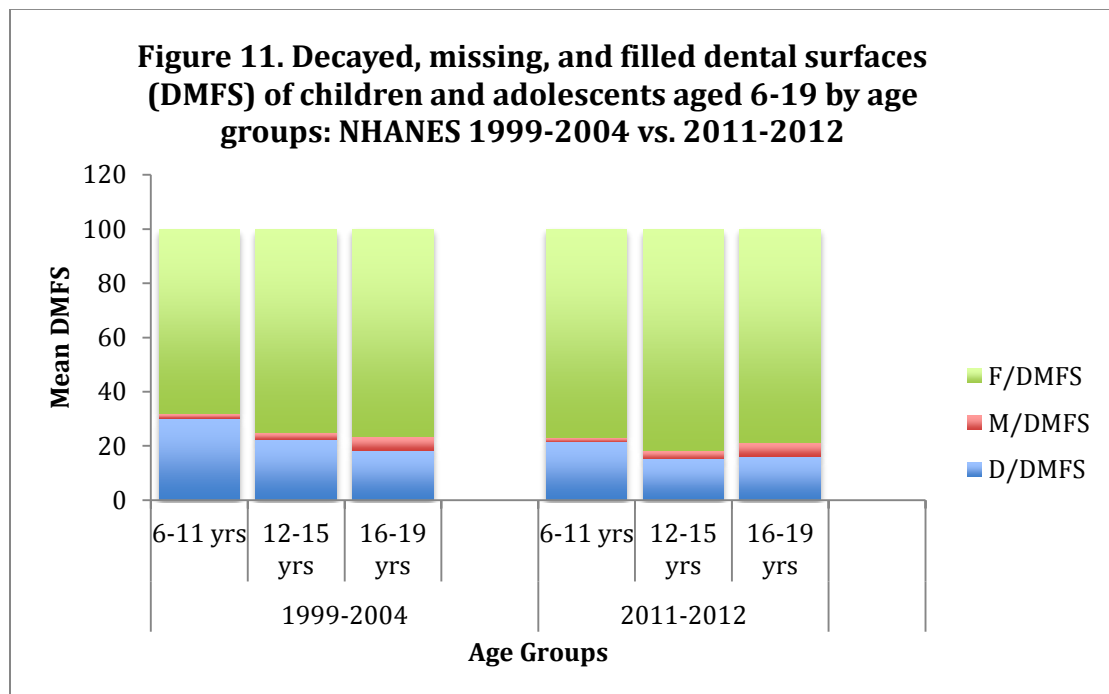
1. OVERALL SAMPLE (6-19 YEARS)

Dental caries experience is further analyzed as decayed, missing and filled teeth percentages, rather than the continuous measure score. In NHANES 1999-2004, the percentage of decayed teeth was 22.3%, and the percentage of filled teeth was 74.2% among people aged 6-19. In NHANES 2011-2012, the percentage of decayed teeth is decreased to 16.9% and the percentage of filled teeth is increase to 79.4%.



2. BY AGE GROUPS

In NHANES 1999-2004, the percentage of decayed teeth was reduced, however the percentage of filled teeth was increased among young adults aged 6-19 compared to children and adolescents. Similar patterns of distribution were found in NHANES 2011-2012, in which the percentage of decayed teeth was decreased and the percentage of filled teeth was increased among young adults compared to children and adolescents.



**3. BIVARIATE TABLE ON THE DISTRIBUTION OF MEAN
DENTAL CARIES EXPERIENCE BY SELECTED FACTORS**

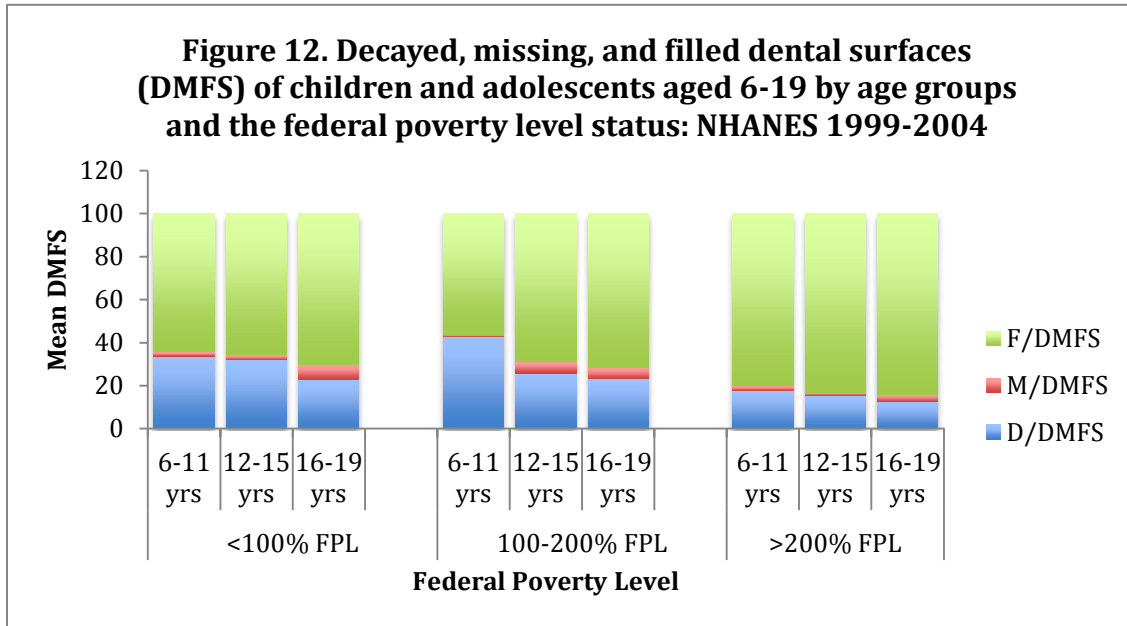
Table 4 demonstrates the bivariate distribution of dental caries experience [which includes treated (filled) and untreated dental caries] according to socio-demographics, oral health perception and dental behavior. In NHANES 1999-2004, the mean DMFS score was significantly higher (p-value <0.0001) among people aged 16-19 (5.6 ± 0.2) compared to people aged 6-11 (0.7 ± 0.05) or 12-15 (2.8 ± 0.2) because they have more permanent teeth to be examined and treated accordingly. In addition, the mean DMFS score was significantly higher in females (2.9 ± 0.1), other races (3.0 ± 0.2) and those living in low Federal Poverty Level (3.3 ± 0.2). Regarding oral health perception, those who have poor perception about their mouth and teeth had significantly higher (p-value <0.0001) mean DMFS score (32.3 ± 1.2) compared to those with excellent (10.0 ± 0.4) or good (16.7 ± 0.5) perception. Moreover, those who had their last dental visit in <12 months had significantly higher (p-value <0.0001) mean DMFS score (2.8 ± 0.1), compared to those who had their last dental visit in 1-5 years (2.6 ± 0.2) or >5 years or never (1.1 ± 0.1), and those who had dental treatment also had significantly higher (p-value <0.0001) mean DMFS score (5.1 ± 0.2), compared to check-up, examination or cleaning (2.2 ± 0.1) or other (2.4 ± 0.4). Similarly in NHANES 2011-2012, people aged 16-19 had significantly higher (p-value <0.0001) mean DMFS score (5.8 ± 0.4) compared to those aged 6-11 (0.8 ± 0.07) or 12-15 (2.9 ± 0.2). The difference in the mean DMFS score between males and females was not statistically significant (p-value=0.96). Also, the difference was not statistically significant (p-value=0.22) among different

race/ethnicity groups. Likewise NHANES 1999-2004, those living in low Federal Poverty Level (3.6 ± 0.5) and those who perceive their mouth and teeth as poor (5.4 ± 1.6) had significantly high mean DMFS score (p-value <0.0001). Regarding dental behavior aspects, differences in the time since last dental visit were not statistically significant (p-value=0.54) and those who visited the dentist for treatment had significantly higher (p-value <0.0001) mean DMFS score (4.7 ± 0.4) compared to those who visited the dentist for check-up, examination or cleaning (2.4 ± 0.2) or other (3.1 ± 0.6).

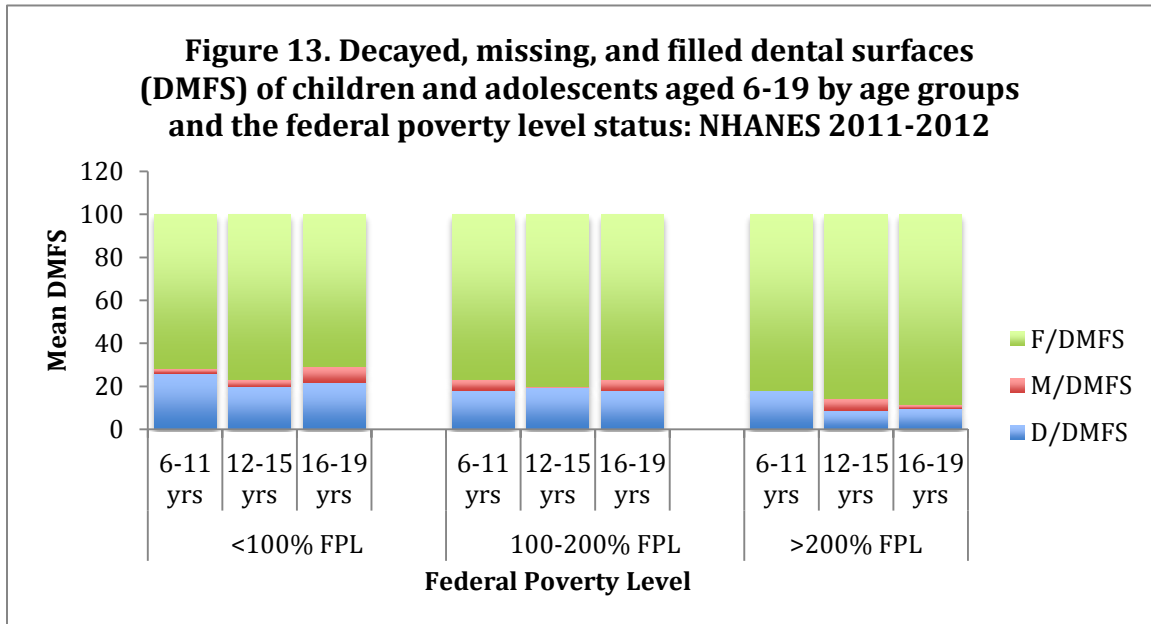
| Table 4. Dental caries experience (mean DMFS) by demographics, OH perception and dental behavior, 1999-2004 compared to 2011-2012 in the United States | | | | |
|---|------------------|----------------|------------------|----------------|
| Variables | 1999-2004 | | 2011-2012 | |
| DMFS | Mean ± SD | P-value | Mean ± SD | P-value |
| Age | | <0.0001 | | <0.0001 |
| 6-11 years | 0.7 ± 0.05 | | 0.8 ± 0.07 | |
| 12-15 years | 2.8 ± 0.2 | | 2.9 ± 0.2 | |
| 16-19 years | 5.6 ± 0.2 | | 5.8 ± 0.4 | |
| Gender | | <0.0001 | | 0.96 |
| Males | 2.4 ± 0.1 | | 2.8 ± 0.2 | |
| Females | 2.9 ± 0.1 | | 2.8 ± 0.2 | |
| Race/Ethnicity | | 0.0007 | | 0.22 |
| Non-Hispanic Whites | 2.6 ± 0.1 | | 2.7 ± 0.2 | |
| Non-Hispanic Blacks | 2.3 ± 0.1 | | 3.0 ± 0.4 | |
| Mexican American | 2.9 ± 0.1 | | 3.3 ± 0.3 | |
| Other race | 3.0 ± 0.2 | | 2.7 ± 0.3 | |
| Federal Poverty Level | | <0.0001 | | <0.0001 |
| Low (<100% FPL) | 3.3 ± 0.2 | | 3.6 ± 0.5 | |
| Medium (100%-199% FPL) | 2.9 ± 0.2 | | 2.9 ± 0.3 | |
| High (>=200% FPL) | 2.1 ± 0.1 | | 2.2 ± 0.3 | |
| OH perception | | <0.0001 | | <0.0001 |
| Excellent | 10.0 ± 0.4 | | 1.9 ± 0.2 | |
| Good | 16.7 ± 0.5 | | 3.9 ± 0.2 | |
| Poor | 32.3 ± 1.2 | | 5.4 ± 1.6 | |
| Time since last dental visit | | <0.0001 | | 0.54 |
| < 12 months | 2.8 ± 0.1 | | 2.8 ± 0.2 | |
| 1-5 years | 2.6 ± 0.2 | | 3.0 ± 0.4 | |
| >5 years or never | 1.1 ± 0.1 | | 2.2 ± 0.7 | |
| Reason of last dental visit | | <0.0001 | | <0.0001 |
| Checkup, examination or cleaning | 2.2 ± 0.1 | | 2.4 ± 0.2 | |
| Treatment | 5.1 ± 0.2 | | 4.7 ± 0.4 | |
| Other | 2.4 ± 0.4 | | 3.1 ± 0.6 | |

4. MEAN DMFS BY SELECTED CHARACTERISTICS

- DMFS by Age Groups and Federal Poverty Status



*The association between mean DMFS and age groups in relation to the federal poverty level is statistically significant. However, p-value=0.27 for F/DMFS by age groups, where federal poverty level is >200%.

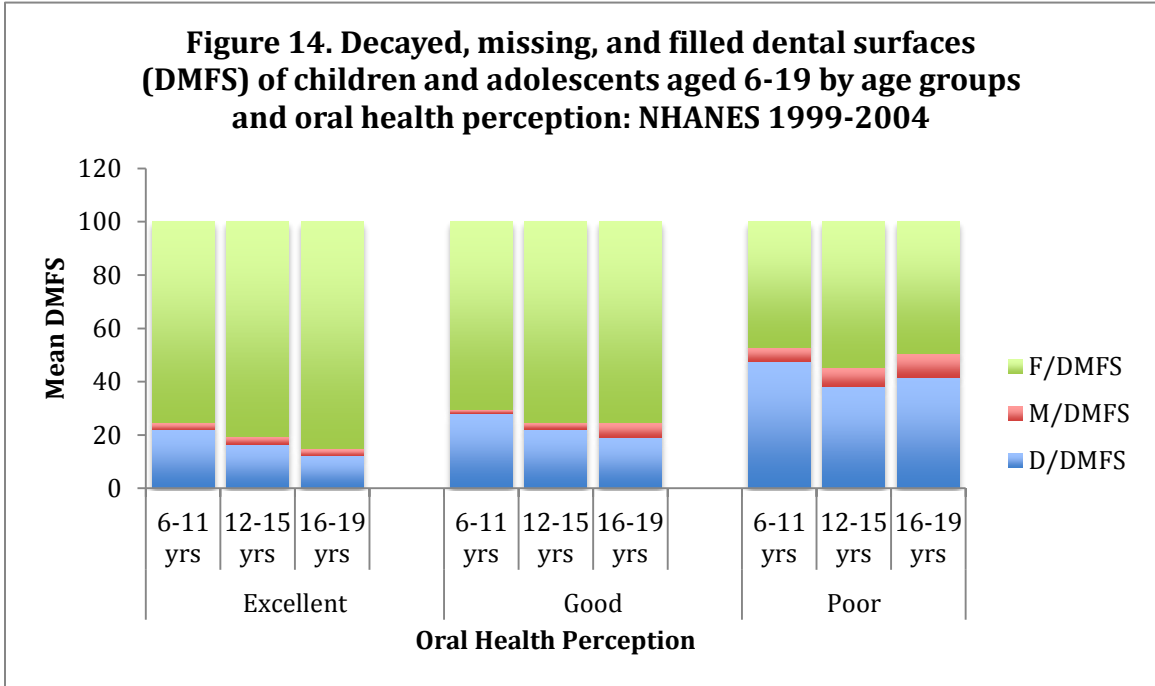


*P-value=0.04 for M/DMFS by age groups, where federal poverty level is <100%.

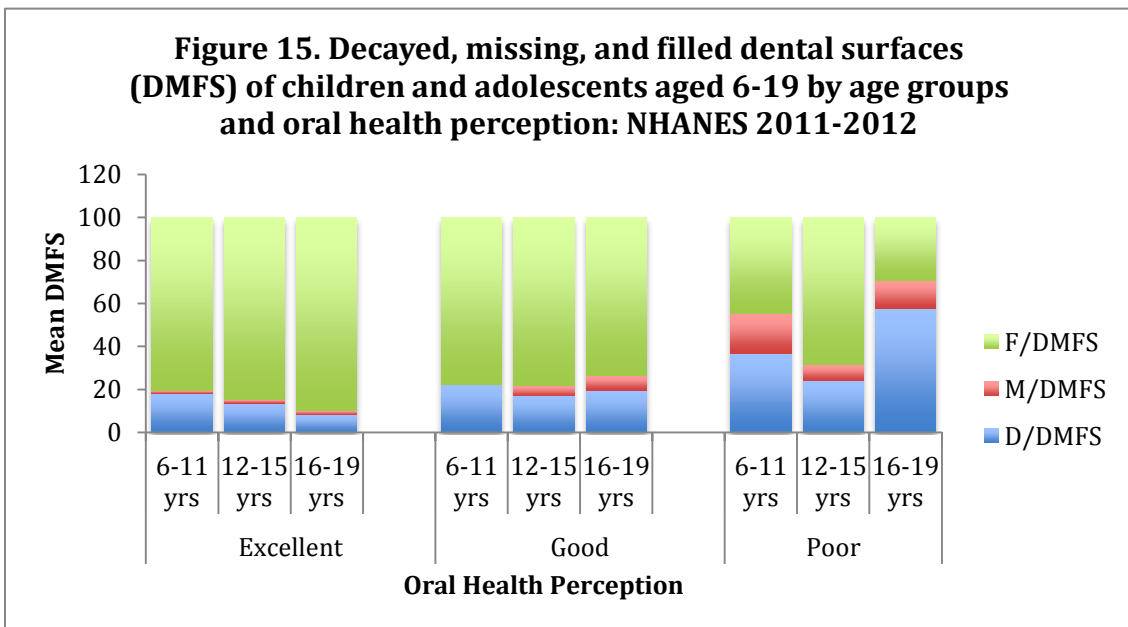
**P-value=0.05 for M/DMFS by age groups, where federal poverty level is 100-200%.

***P-value=0.03 for M/DMFS by age groups, where federal poverty level is >200%.

- **DMFS by Age Groups and Oral Health Perception**

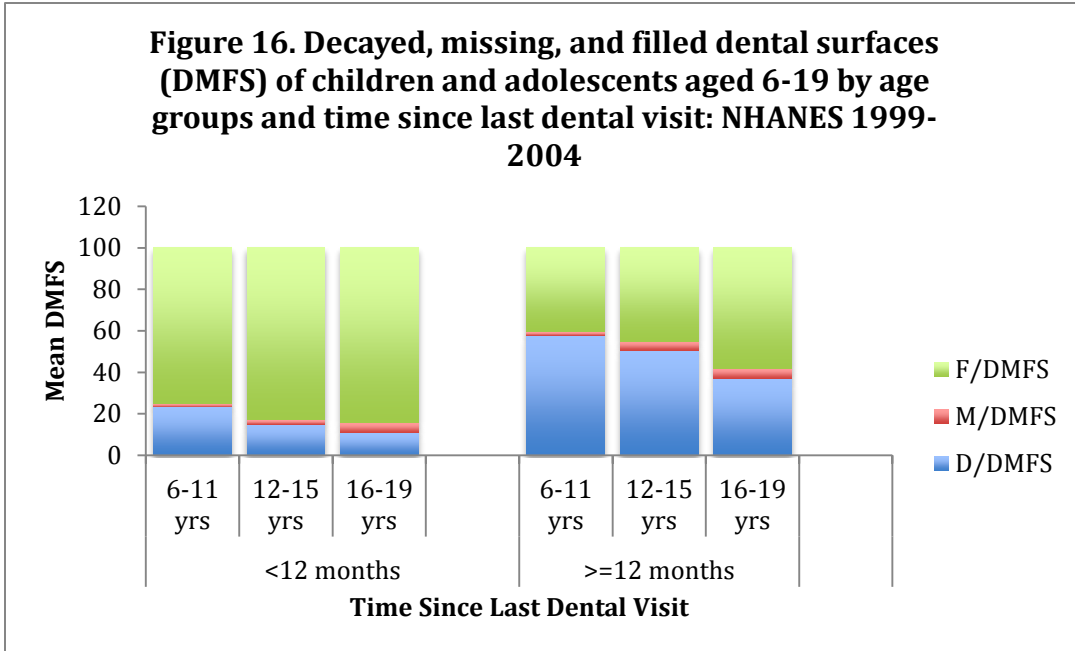


*The association between mean DMFS and age groups in relation to excellent and good oral health perceptions is statistically significant. However, p-value=0.89 for M/DMFS by age groups, where oral health perception is Excellent.
 **The association between mean DMFS and age groups in relation to poor oral health perception is not statistically significant.

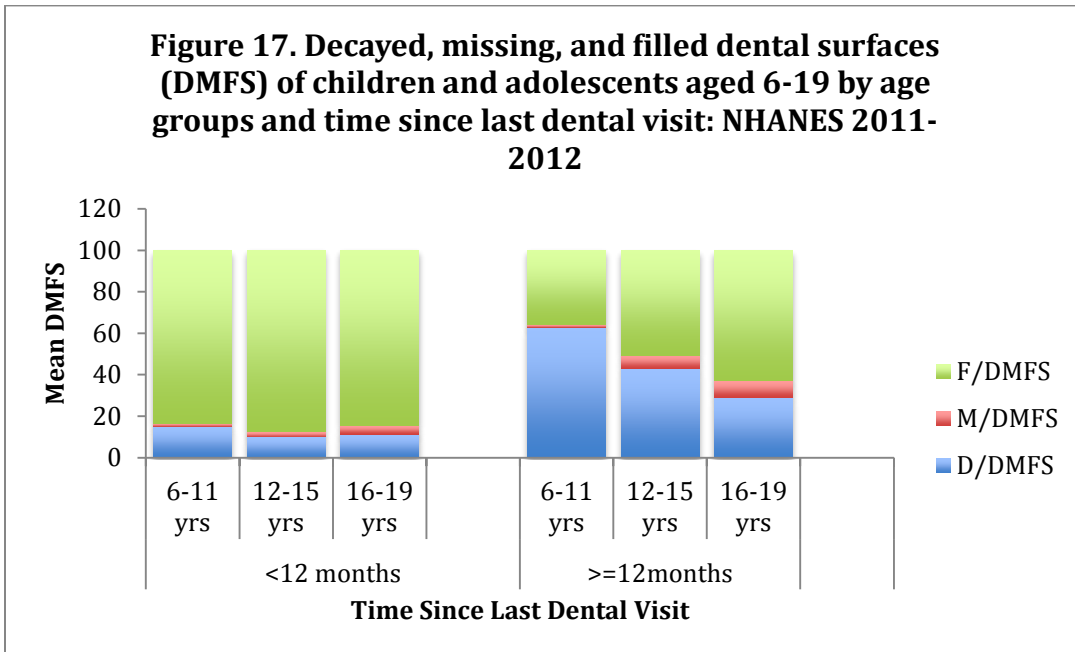


*P-value=0.001 for M/DMFS by age groups, where oral health perception is good.

- **DMFS by Age Groups and Time Since Last Dental Visit**



*The association between age groups and time since last dental visit <12 months is statistically significant (P-value <0.0001). Similarly the association between age groups and time since last dental visit ≥12 months is statistically significant.



*P-value<0.0006 for D/DMFS, p-value=0.008 for F/DMFS by age groups, where time to last dental visit is ≥12 months.

**II. OBJECTIVE II: THE ASSOCIATION BETWEEN DENTAL CARIES AND
DENTAL FLUOROSIS AT THE INDIVIDUAL LEVEL**

**a. THE RELATIONSHIP BETWEEN DENTAL CARIES AND
FLUOROSIS**

i. NHANES 1999-2004

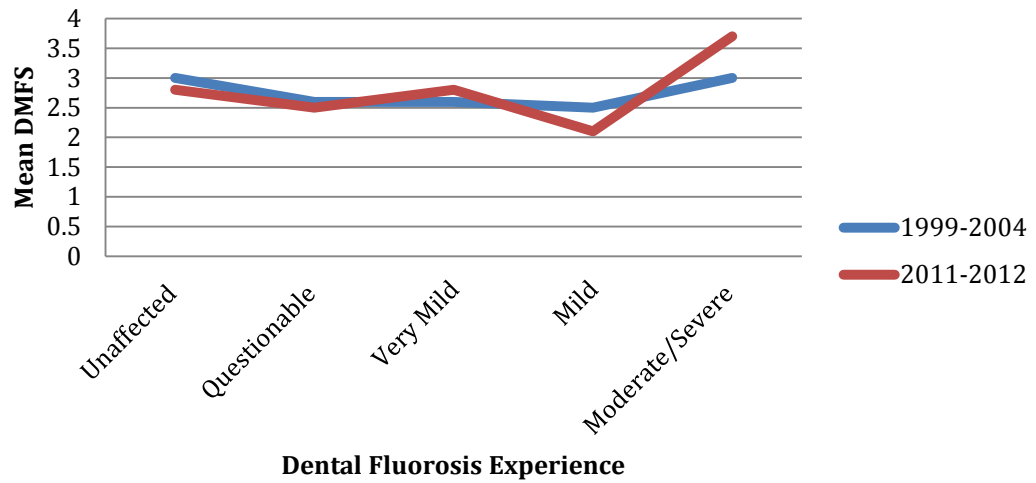
Analyzing the data from NHANES 1999-2004 shows that the crude association between dental fluorosis and dental caries, which is measured by DMFS score, is significantly negative (p -value=0.05) for the milder forms of fluorosis among people aged 6-19. However, there is a positive relationship between the two conditions for the moderate or severe forms of fluorosis among people of the same age group. This can be explained that people with severe forms of fluorosis are having a lower percentage of untreated decayed teeth and a higher percentage of filled teeth. Therefore, they will have a higher score of DMFS that reflects their overall caries experience.

ii. NHANES 2011-2012

Analyzing the data from NHANES 2011-2012 shows that the crude association between dental fluorosis and dental caries is following almost the same trend as NHANES 1999-2004. Although the caries experience is significantly decreased among people aged 6-19 with mild fluorosis, it is increased among people of the same age group with very mild and moderate/severe forms of fluorosis. The relationship between dental fluorosis and DMFS is statistically significant (p -value=0.03).

| Table 5: The crude association between dental fluorosis and dental caries, (1999-2004 vs. 2011-2012) in the United States | | | | | | |
|--|------------|--------------|-----------|-----------|---------------------|---------|
| Variables | | | | | | |
| Fluorosis 6-19 years | Unaffected | Questionable | Very Mild | Mild | Moderate/ Severe | P-value |
| 1999-2004 DMFS (Mean ± SE) | 3.0 ± 0.2 | 2.6 ± 0.2 | 2.6 ± 0.2 | 2.5 ± 0.2 | 3.0 ± 0.3 | 0.05 |
| 2011-2012 DMFS (Mean ± SE) | 2.8 ± 0.2 | 2.5 ± 0.5 | 2.8 ± 0.3 | 2.1±0.3 | 3.7 ± 0.4 | 0.03 |

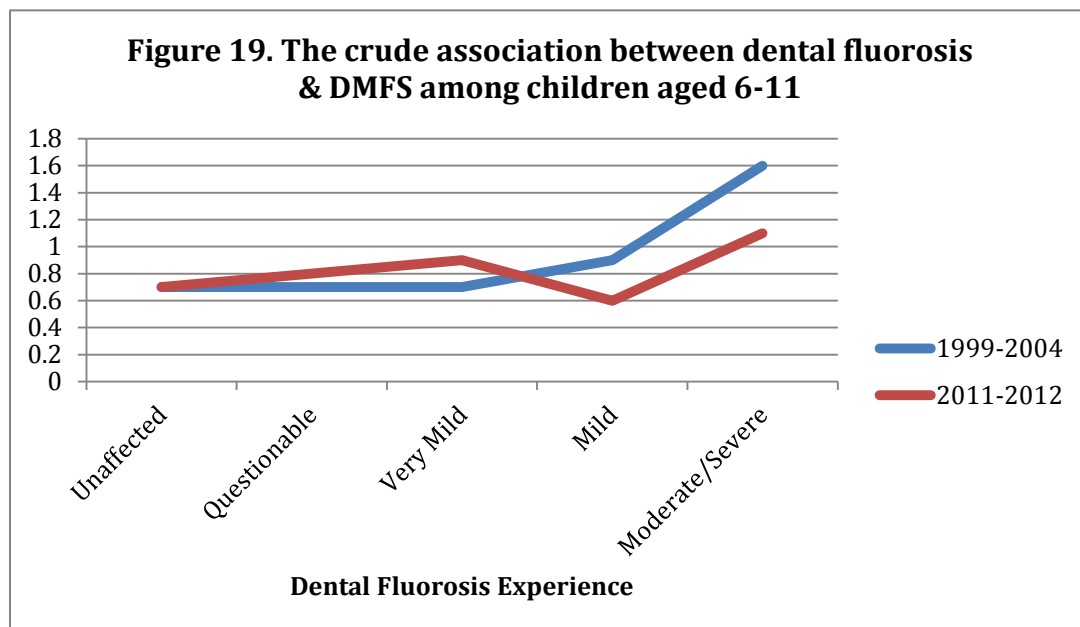
Figure 18. The crude association between dental fluorosis & DMFS among persons aged 6-19 (1999-2004 vs. 2011-2012)



**b. COMPARISON OF THE RELATIONSHIP BETWEEN DENTAL
CARIES AND FLUOROSIS BY AGE GROUPS**

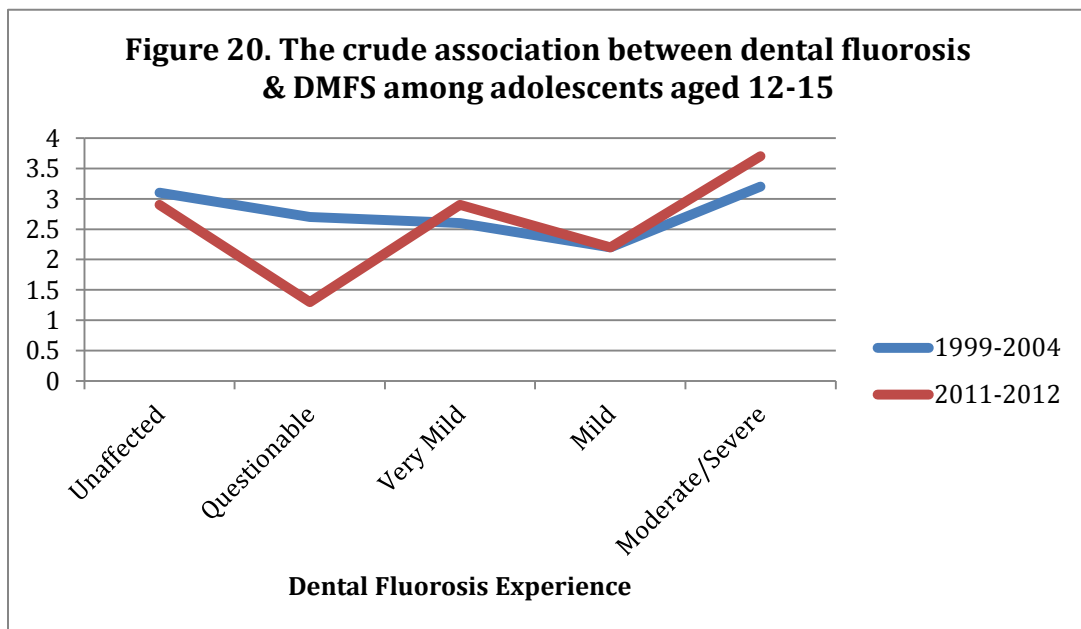
i. CHILDREN AGED 6-11 YEARS

In NHANES 1999-2004, dental fluorosis severity was linearly associated with higher DMFS scores among children aged 6-11 years. Children with moderate/severe fluorosis experience had the highest DMFS scores compared to other levels of fluorosis. In NHANES 2011-2012, similar relationship between dental fluorosis severity and DMFS was encountered, however, children with mild fluorosis had lower DMFS scores compared to children with no fluorosis. Still, children with moderate/severe fluorosis had the highest DMFS scores compared to children with other levels of fluorosis.



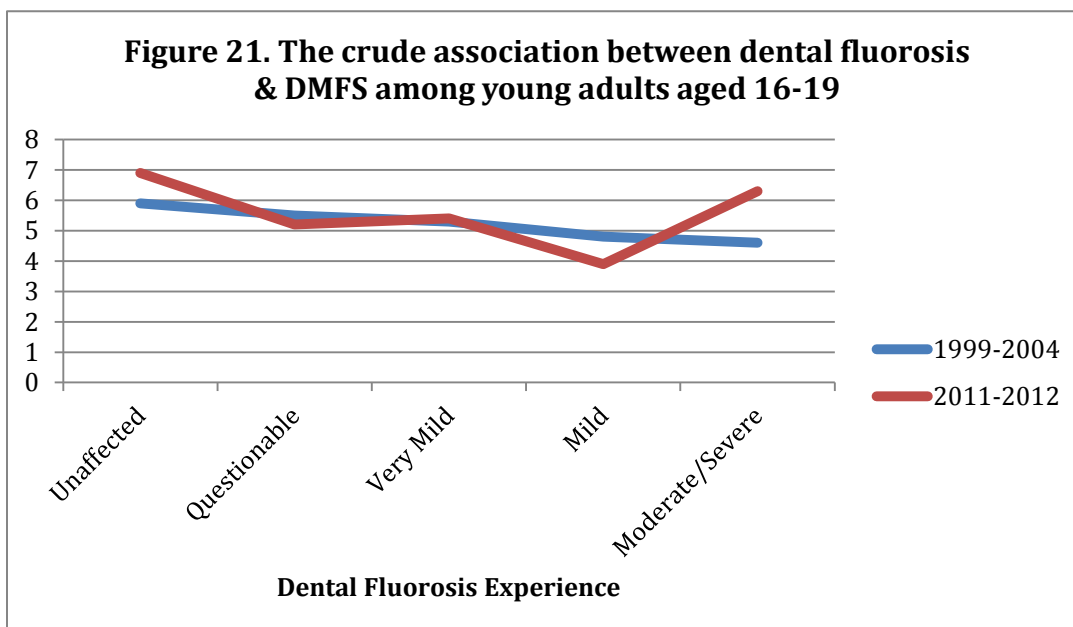
iii. ADOLESCENTS AGED 12-15 YEARS

In NHANES 1999-2004, adolescents' aged 12-15 with very mild or mild dental fluorosis had lower DMFS scores compared to adolescents of the same age group with no fluorosis. However, adolescents with moderate/severe dental fluorosis had higher DMFS score compared to adolescents with no fluorosis. Again, the reason behind this linear relationship is that those adolescents are having a higher percentage of filled teeth that affect the DMFS score directly. In NHANES 2011-2012, the relationship between dental fluorosis severity and DMFS is variable. Adolescents with mild fluorosis had lower DMFS score compared to those with no fluorosis and adolescents with moderate/severe fluorosis had the highest DMFS scores compared to those with other levels of fluorosis.



iv. YOUNG ADULTS AGED 16-19 YEARS

In NHANES 1999-2004, young adults aged 16-19 years showed different direction of the relationship between dental fluorosis severity and DMFS compared to children and adolescents. The relationship between the two conditions is inversely proportional, in which persons with higher dental fluorosis severity are having lower DMFS scores. Young adults with moderate/severe fluorosis had lower DMFS score compared to young adults with no fluorosis. However, this relationship between dental fluorosis severity and DMFS was less linear for young adults in NHANES 2011-2012. The relationship was similar to that in adolescents, in which having mild fluorosis is associated with lower DMFS score compared to those with no fluorosis, and those with moderate/severe fluorosis are having higher DMFS score compared to other severity levels of fluorosis, but most importantly DMFS score in that category is still lower than those with no fluorosis.



c. **LINAER REGRESSION MODEL ON THE ASSOCIATION BETWEEN DENTAL CARIES AND FLUOROSIS AFTER CONTROLLING FOR CONFOUNDING**

i. **NHANES 1999-2004**

Table 6-1 shows the multivariable linear regression model, where the mean score of dental caries is the dependent variable and dental fluorosis is the main predictor, adjusted for socio-demographics and dental behavior aspects in NHANES 1999-2004. The model illustrates that dental caries experience increases with higher severity levels of dental fluorosis, however this relationship is not statistically significant, controlling for covariates. By looking at different socio-demographic factors in relation to dental caries experience, it was found that people aged 16-19 had significantly higher mean DMFS score (B-estimate=4.8, p-value <0.0001) compared to those aged 6-11. In addition, females had significantly higher mean DMFS score (B-estimate= 0.3, p-value= 0.02) compared to males. The differences between different race/ethnicity groups were not statistically significant in relation to mean DMFS score except for Non-Hispanic Blacks, who had lower caries experience compared to Non-Hispanic Whites (B-estimate=-0.4, p-value=0.05). Moreover, those living in high Federal Poverty Level had significantly lower mean DMFS score (B-estimate= -1.3, p-value <0.0001) compared to those living in low Federal Poverty Level. Regarding dental behavior aspects, those who had their last dental visit in >5 years or never had significantly lower mean DMFS score (B-estimate= -3.0, p-value <0.0001) compared to those who had their last dental visit in <12 months. In addition, compared to those who had dental check-up, examination or cleaning in their

last dental visit, those who had dental treatment had significantly higher dental caries experience (B-estimate= 2.5, p-value <0.0001).

| Table 6-1: Multivariable linear regression model to predict caries outcome (mean DMFS) in 1999-2004 | | |
|--|-------------------|----------------|
| | 1999-2004 | |
| | B-estimate | P-value |
| Intercept | 0.8 | 0.02 |
| Dental fluorosis | | |
| Unaffected | Reference | |
| Questionable | -0.02 | 0.9 |
| Very mild | -0.2 | 0.4 |
| Mild | -0.2 | 0.3 |
| Moderate/ Severe | 0.1 | 0.7 |
| Age | | |
| 6-11 years | Reference | |
| 12-15 years | 2.2 | <0.0001 |
| 16-19 years | 4.8 | <0.0001 |
| Gender | | |
| Males | Reference | |
| Females | 0.3 | 0.02 |
| Race/ethnicity | | |
| Non-Hispanic Whites | Reference | |
| Non-Hispanic Blacks | -0.4 | 0.05 |
| Mexican American | 0.4 | 0.09 |
| Other | 0.1 | 0.7 |
| Poverty Status | | |
| Low (<100% FPL) | Reference | |
| Medium (100%-199% FPL) | -0.2 | 0.4 |
| High (>=200% FPL) | -1.3 | <0.0001 |
| Time since last dental visit | | |
| <12 months | Reference | |
| 1-5 years | -1.0 | <0.0001 |
| >5 years or never | -3.0 | <0.0001 |

| Reason for last dental visit | | |
|-------------------------------------|-----------|---------|
| Checkup, examination, or cleaning | Reference | |
| Treatment | 2.5 | <0.0001 |
| Other | 0.03 | 0.9 |

ii. NHANES 2011-2012

Table 6-2 shows the multivariable linear regression model, where mean score of dental caries is the dependent variable and dental fluorosis is the main predictor adjusted for socio-demographics and dental behavior aspects in NHANES 2011-2012. The model illustrates that dental caries experience increases with higher severity levels of dental fluorosis. This relationship is only statistically significant for mild dental fluorosis, where the mean DMFS score decreases with mild fluorosis (B-estimate= -0.9, p-value=0.004), controlling for covariates. In this model, different socio-demographic factors were taken into consideration to control for confounders. It was found that differences in different age groups in relation to mean DMFS score were statistically significant. Adolescents aged 12-15 (B-estimate= 2.3, p-value=<0.0001), and young adults aged 16-19 (B-estimate= 4.9, p-value <0.0001) had significantly higher caries experience compared to children aged 6-11. The differences between gender, different race/ethnicity groups, and income levels were not statistically significant in relation to caries experience. Regarding dental behavior aspects, those who had their last dental visit in >5 years or never had significantly lower mean DMFS score (B-estimate= -2.6, p-value 0.01) compared to those who had their last dental visit in <12 months. In addition, those who had dental treatment had significantly higher dental caries experience (B-estimate= 1.8, p-value= 0.0003) compared to those who had dental check-up, examination or cleaning in their last dental visit.

| Table 6-2: Multivariable linear regression model to predict caries outcome (mean DMFS) in 2011-2012 | | |
|--|-------------------|----------------|
| | 2011-2012 | |
| | B-estimate | P-value |
| Intercept | 1.9 | 0.004 |
| Dental fluorosis | | |
| Unaffected | Reference | |
| Questionable | -0.8 | 0.2 |
| Very mild | -0.6 | 0.1 |
| Mild | -0.9 | 0.004 |
| Moderate/ Severe | 0.6 | 0.2 |
| Age | | |
| 6-11 years | Reference | |
| 12-15 years | 2.3 | <0.0001 |
| 16-19 years | 4.9 | <0.0001 |
| Gender | | |
| Males | Reference | |
| Females | -0.2 | 0.3 |
| Race/ethnicity | | |
| Non-Hispanic Whites | Reference | |
| Non-Hispanic Blacks | -0.1 | 0.8 |
| Mexican American | 0.3 | 0.5 |
| Other | -0.1 | 0.7 |
| Poverty Status | | |
| Low (<100% FPL) | Reference | |
| Medium (100%-199% FPL) | -0.7 | 0.3 |
| High (>=200% FPL) | -1.4 | 0.1 |
| Time since last dental visit | | |
| <12 months | Reference | |
| 1-5 years | -0.5 | 0.2 |
| >5 years or never | -2.6 | 0.01 |

| Reason for last dental visit | | |
|-------------------------------------|-----------|--------|
| Checkup, examination, or cleaning | Reference | |
| Treatment | 1.8 | 0.0003 |
| Other | -0.4 | 0.6 |

d. THE ASSOCIATION BETWEEN DENTAL CARIES AND FLUOROSIS
IN CHILDREN AGED 8-9 YEARS (1999-2004)

To evaluate whether an exposure to fluoride in the early years of life has caries preventive effect on permanent teeth, explanatory regression models were generated for children aged 8-9 years, adjusting for other potential contributory factors. Table (7-1) demonstrates a multivariable linear regression model, where the mean DMFS score is the dependent variable, and dental fluorosis is the main predictor, controlling for age, gender, race/ethnicity, poverty status and dental behavior (time since last dental visit and its reason). In this analysis, dental fluorosis is binary (no/yes), in which “no” represents people who are unaffected and those who had questionable lesions, and “yes” represents those with very mild, mild, moderate and severe fluorosis. The mean DMFS score was decreased in children aged 8-9 with dental fluorosis compared to children of the same age group with no dental fluorosis; however, this relationship was not statistically significant (B-estimate= -0.2, p-value= 0.3), controlling for socio-demographics and dental behavior. The differences in gender and different race/ethnicity groups in regard to mean DMFS score were not statistically significant. Children living in high Federal Poverty Level had significantly lower mean DMFS score compared to children living in low Federal Poverty Level (B-estimate=-0.05, p-value=0.02). Regarding dental behavior aspects, children whose last dental visit was in 1-5 years (B-estimate= -0.3, p-value= 0.006) or >5 years or never (B-estimate= -0.7, p-value= 0.01) had significantly lower caries experience compared to those whose last dental visit in <12 months. In addition, children who visited the dentist for dental treatment (B-estimate= 0.7, p-value= 0.03) had significantly

higher mean DMFS score compared to children who visited the dentist for check-up, examination or cleaning.

Furthermore, table (7-2) shows a multivariable logistic model created to predict the association between dental caries (DMFS>0) and dental fluorosis in children aged 8-9, controlling for other covariates. Again, dental fluorosis in this model is binary (no/yes). The model illustrates that those children aged 8-9 with dental fluorosis had 0.8 times the odds of having dental caries (DMFS>0) on permanent teeth compared to children of the same age group with no dental fluorosis. Again, this relationship was not statistically significant (95% CI= 0.4-1.3). The differences in gender and different race/ethnicity groups in regard to dental caries were not statistically significant. Children living in $\geq 200\%$ Federal Poverty Level had 0.5 times the odds of having DMFS>0 compared to those living in $< 100\%$ Federal Poverty Level of the same age group. Regarding dental behavior, children who had dental treatment had 2.2 times the odds of having dental caries (DMFS>0) compared to children who had check-up, examination or cleaning.

| Table 7-1: Multivariable linear regression model to predict the association between dental caries, as a dependent variable, and dental fluorosis at the age 8-9 years, adjusting for other variables (1999-2004) | | |
|---|-------------------|----------------|
| | B-estimate | P-value |
| Intercept | 0.6 | 0.07 |
| Dental fluorosis | | |
| No | Reference | |
| Yes | -0.2 | 0.3 |
| Gender | | |
| Males | Reference | |
| Females | 0.2 | 0.2 |
| Race/ethnicity | | |
| Non-Hispanic Whites | Reference | |
| Non-Hispanic Blacks | -0.1 | 0.4 |
| Mexican American | 0.2 | 0.4 |
| Other | -0.2 | 0.4 |
| Poverty Status | | |
| Low (<100% FPL) | Reference | |
| Medium (100%-199% FPL) | -0.2 | 0.3 |
| High (>=200% FPL) | -0.5 | 0.02 |
| Time since last dental visit | | |
| <12 months | Reference | |
| 1-5 years | -0.3 | 0.006 |
| >5 years or never | -0.7 | 0.01 |
| Reason for last dental visit | | |
| Checkup, examination, or cleaning | Reference | |
| Treatment | 0.7 | 0.03 |
| Other | 0.3 | 0.5 |

* $R^2=0.05$. Data were weighted to correct for different sampling ratios.

| Table 7-2: Multivariable logistic regression model to predict the association between dental caries (DMFS>0), as a dependent variable, and dental fluorosis at the age 8-9 years, adjusting for other variables (1999-2004) | | |
|---|-------------------|---------------|
| | Odds Ratio | 95% CI |
| Dental fluorosis | | |
| No | Reference | |
| Yes | 0.8 | 0.4-1.3 |
| Gender | | |
| Males | Reference | |
| Females | 1.2 | 0.9-1.7 |
| Race/ethnicity | | |
| Non-Hispanic Whites | Reference | |
| Non-Hispanic Blacks | 0.8 | 0.5-1.5 |
| Mexican American | 1.4 | 0.9-2.3 |
| Other | 1.0 | 0.5-2.2 |
| Poverty Status | | |
| Low (<100% FPL) | Reference | |
| Medium (100%-199% FPL) | 0.8 | 0.4-1.5 |
| High (>=200% FPL) | 0.5 | 0.3-0.9 |
| Time since last dental visit | | |
| <12 months | Reference | |
| 1-5 years | 0.6 | 0.4-1.0 |
| >5 years or never | <0.001 | <0.001-<0.001 |
| Reason for last dental visit | | |
| Checkup, examination, or cleaning | Reference | |
| Treatment | 2.2 | 1.4-3.6 |
| Other | 1.6 | 0.4-7.3 |

*(c=0.67). Data were weighted to correct for different sampling ratios.

III. OBJECTIVE III: THE ASSOCIATION BETWEEN OHRQOL AND DENTAL

FLUOROSIS (NHANES 2003-2004)

a. THE DISTRIBUTION OF ORAL HEALTH RELATED QUALITY OF

LIFE (OHRQoL) MEASURES

| Table 8: The distribution (n,%) of OHRQoL 7-questions' responses | | |
|---|--------------------------------|------------------|
| OHRQoL questions | 2003-2004 (16-49 years) | |
| | n | Weighted% |
| Painful activity in mouth | | |
| 1=Never | 1690 | 55.0 |
| 2=Hardly ever | 713 | 24.2 |
| 3= Occasionally | 422 | 14.2 |
| 4= Often | 198 | 6.6 |
| Life less satisfying because of mouth | | |
| 1=Never | 2504 | 82.2 |
| 2=Hardly ever | 276 | 9.1 |
| 3= Occasionally | 150 | 5.3 |
| 4= Often | 92 | 3.4 |
| Difficulty doing usual jibs or attending school because of oral problems | | |
| 1=Never | 2758 | 91.4 |
| 2=Hardly ever | 164 | 5.4 |
| 3= Occasionally | 58 | 2.1 |
| 4=Often | 43 | 1.2 |
| Uncomfortable eating any food because of mouth | | |
| 1=Never | 2780 | 92.4 |
| 2=Hardly ever | 141 | 4.4 |
| 3= Occasionally | 68 | 2.2 |
| 4= Often | 32 | 1.0 |

| | | |
|---|------|------|
| Sense of taste affected because of mouth | | |
| 1=Never | 2304 | 74.9 |
| 2=Hardly ever | 299 | 9.9 |
| 3= Occasionally | 268 | 9.9 |
| 4=Often | 151 | 5.3 |
| Avoided particular foods because of mouth | | |
| 1=Never | 2225 | 72.6 |
| 2=Hardly ever | 345 | 11.5 |
| 3= Occasionally | 327 | 11.6 |
| 4= Often | 125 | 4.2 |
| Self-conscious or embarrassed because of mouth | | |
| 1=Never | 2499 | 80.9 |
| 2=Hardly ever | 204 | 7.3 |
| 3= Occasionally | 177 | 6.3 |
| 4=Often | 142 | 5.5 |

Table 8 details the distribution of the original items related to OHRQoL, showing that the most often reported OHRQoL concern was “painful activity in the mouth” at 6.6% of the population. The least often reported OHRQoL concerns were “uncomfortable eating any food” at (1%) and “difficulty doing usual jobs or attending school ” at (1.2%).

The overall OHRQoL mean for the entire population is **9.6** (range= 6-28), which tends to be towards the lower end of the range, indicating that most of the people perceive their oral health as “good” in terms of not having any oral problems.

Psychological & social disability domain is considered as the sum of questions 2,3 & 7 of OHRQoL, which are:

2) How often during last year have you felt life in general was less satisfying because of problems with your teeth, mouth, or dentures?

3) How often during last year have you had difficulty doing your usual jobs or attending school because of problems with teeth, mouth, or dentures?

7) How often during last year have you been self-conscious or embarrassed because of your teeth, mouth, or dentures?

The mean psychological OHRQoL=3.8 (range=2-12)

Physical/ functional disability domain is considered as the sum of questions 1, 4, 5 & 6 of OHRQoL, which are:

1) How often during last year have you had painful aching anywhere in your mouth?

4) How often during last year has your sense of taste been affected by problems with your teeth, mouth, or dentures?

5) How often during last year have you avoided particular food because of problems with your teeth, mouth, or dentures?

6) How often during last year have you found it uncomfortable to eat any food because of problems with your teeth, mouth, or dentures?

The mean physical OHRQoL=5.8 (range=3-16)

b. THE MEAN OHRQoL ASSOCIATION WITH DENTAL FLUOROSIS AND CARIES

i. THE ASSOCIATION BETWEEN OHRQOL AND DENTAL FLUOROSIS

Among people aged 16-49, having higher levels of dental fluorosis will result in lower scores of OHRQoL denoting better OHRQoL. Similar results were found for psychological and physical OHRQoL with fluorosis experience. This relationship is almost the same for all teeth, anterior teeth and posterior teeth analyses. The reason behind this inverse relationship is that people with higher fluorosis experience are having lower DMFS scores, which have a high impact on people's perception on OHRQoL. This means that having lower DMFS scores because of having dental fluorosis will affect OHRQoL measures positively.

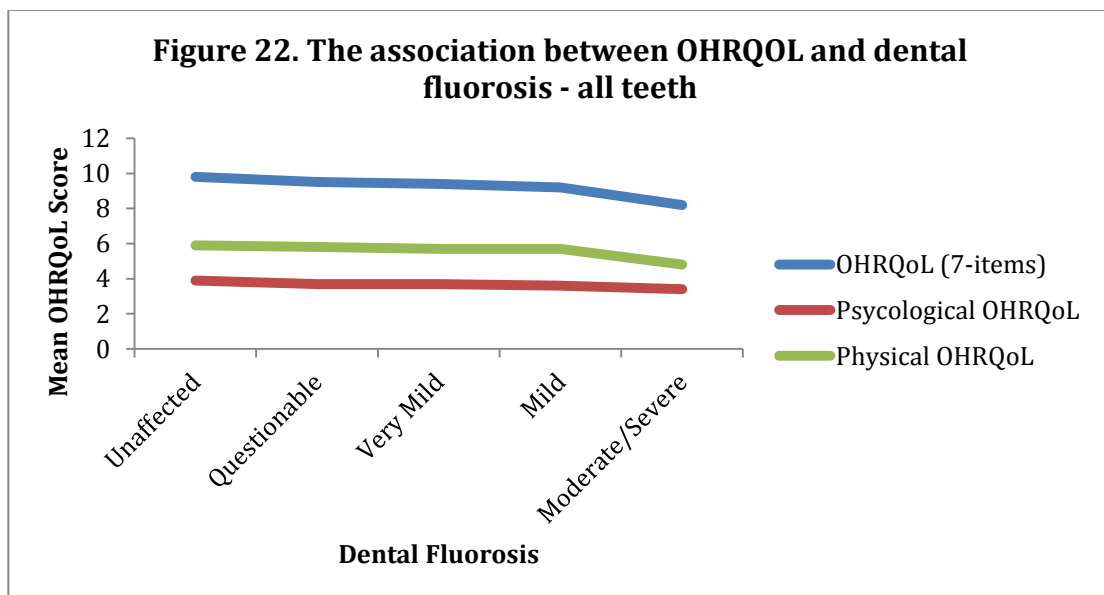


Figure 23. The association between OHRQoL and dental fluorosis - anterior teeth

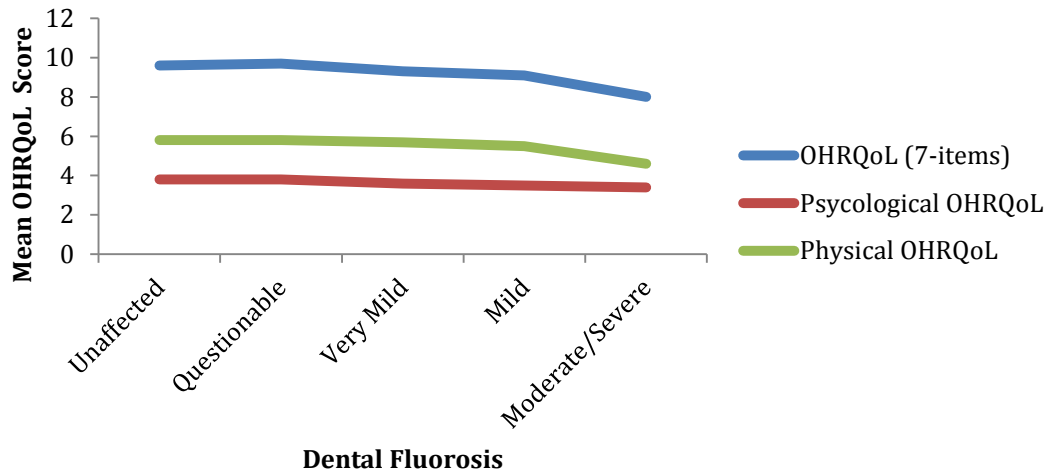
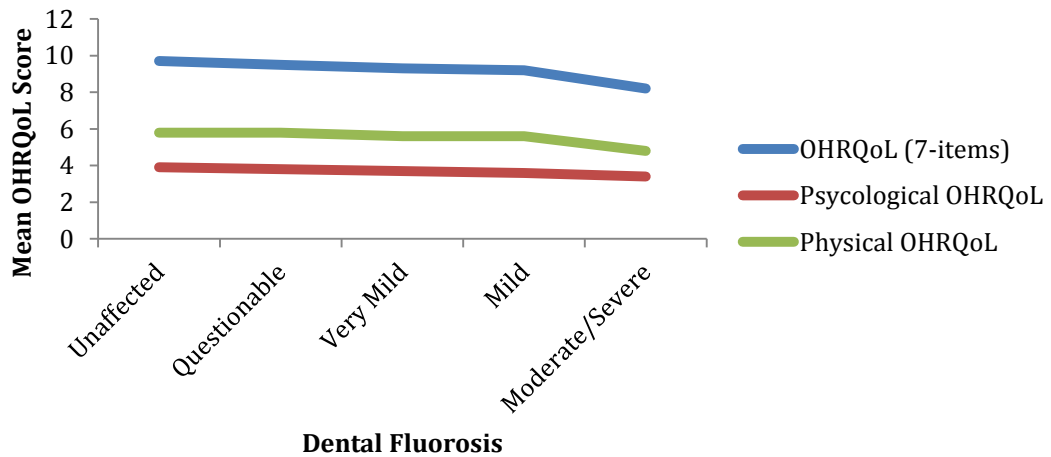


Figure 24. The association between OHRQoL and dental fluorosis - posterior teeth



ii. **THE ASSOCIATION BETWEEN OHRQoL AND DENTAL CARIES**

The relationship between dental caries and OHRQoL is linear, which is the opposite of the relationship between dental fluorosis and OHRQoL. Among people aged 16-49, having higher scores of DMFS will result in higher scores of OHRQoL, denoting worse OHRQoL, because people will suffer from the complications of dental caries, such as pain, discomfort, or loss of school or work hours, which will affect OHRQoL negatively. This relationship between dental caries and OHRQoL is maintained in all teeth, anterior teeth and posterior teeth analyses with the three measures of OHRQoL (overall, psychological and physical).

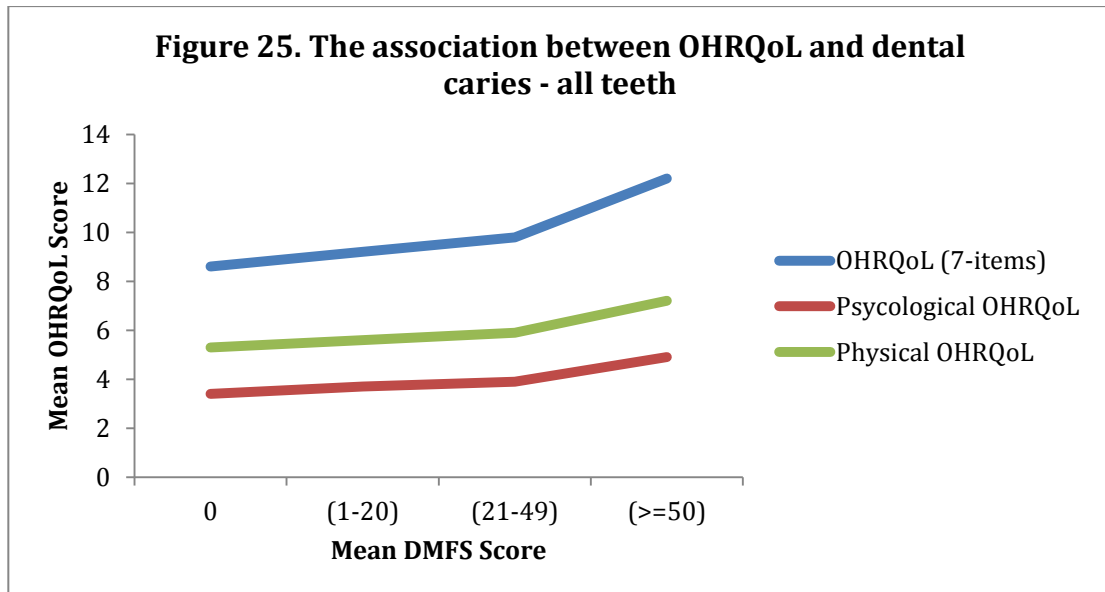


Figure 26. The association between OHRQoL and dental caries- anterior teeth

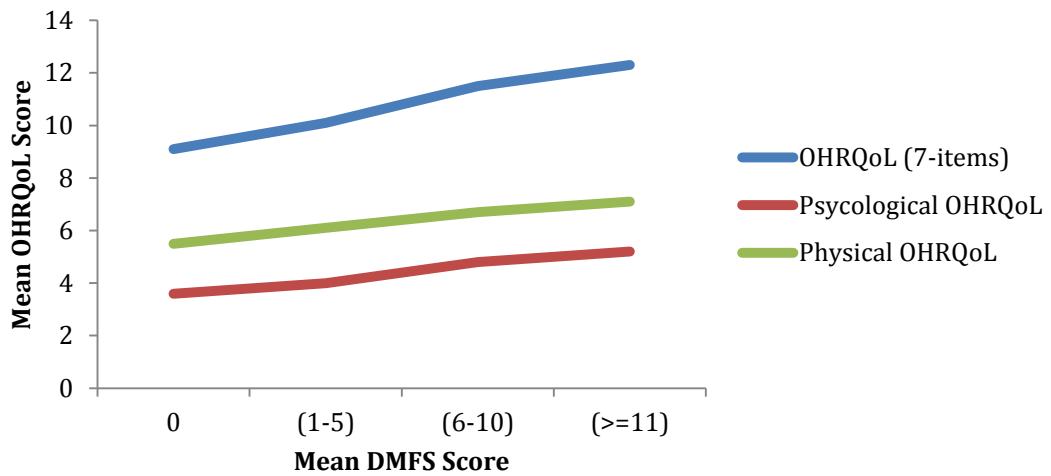
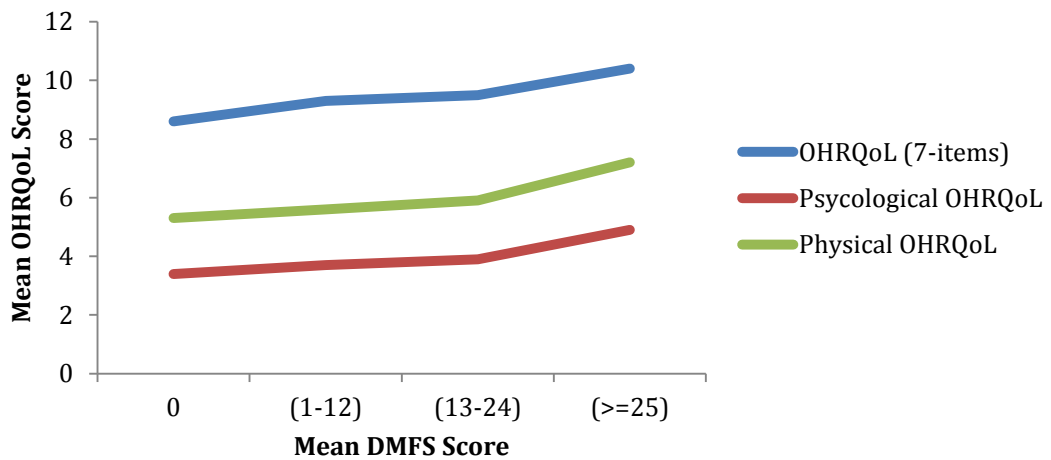


Figure 27. The association between OHRQoL and dental caries - posterior teeth



iii. **THE ASSOCIATION BETWEEN MEAN OHRQoL WITH BOTH DENTAL FLUOROSIS AND CARIES**

The bivariate analysis results for all teeth are shown in Table 8, which provides a breakdown of OHRQoL (overall OHRQoL, psychological OHRQoL and physical OHRQoL) and DMFS scores by dental fluorosis experience. There was a statistically significant inverse relationship between dental fluorosis and overall OHRQoL (i.e., the higher fluorosis severity, the better OHRQoL) with a p-value=0.006. Similar results were found for psychological and physical OHRQoL with fluorosis experience (p-value=0.02 and 0.1, respectively). There was also a statistically significant inverse relationship between dental fluorosis and DMFS with a p-value <0.0001. The lower DMFS scores explain the better perception of oral health (lower OHRQoL scores) in higher fluorosis severity groups.

| Table 9: Bivariate analysis of dental fluorosis with OHRQoL and DMFS for all teeth (2003-2004) | | | | |
|---|-------------------------|---------------------------------|----------------------------|-------------|
| Fluorosis Mean (SD)^(A) | NHANES 2003-2004 | | | |
| | OHRQoL (7-items) | Psychological OHRQoL (B) | Physical OHRQoL (C) | DMFS |
| Unaffected | 9.8 (0.2) | 3.9 (0.1) | 5.9 (0.1) | 22.2 (0.5) |
| Questionable | 9.5 (0.1) | 3.7 (0.1) | 5.8 (0.1) | 16.3 (0.9) |
| Very mild | 9.4 (0.2) | 3.7 (0.1) | 5.7 (0.1) | 11.5 (0.5) |
| Mild | 9.2 (0.3) | 3.6 (0.1) | 5.7 (0.2) | 10.8 (0.8) |
| Moderate/ severe | 8.2 (0.3) | 3.4 (0.1) | 4.8 (0.1) | 10.5 (1.8) |
| P-value | 0.006 | 0.02 | 0.01 | <0.0001 |

(A) For the mean and standard error, numbers are rounded up to the first digit after the decimal. Lower means denote better OHRQoL and vice versa.

(B) Psychological & social disability domain is considered as the sum of questions 2,3 & 7 of OHRQoL, which are:

2) How often during last year have you felt life in general was less satisfying because of problems with your teeth, mouth, or dentures?

3) How often during last year have you had difficulty doing your usual jobs or attending school because of problems with teeth, mouth, or dentures?

7) How often during last year have you been self-conscious or embarrassed because of your teeth, mouth, or dentures?

(C) Physical/ functional disability domain is considered as the sum of questions 1, 4, 5 & 6 of OHRQoL, which are:

1) How often during last year have you had painful aching anywhere in your mouth?

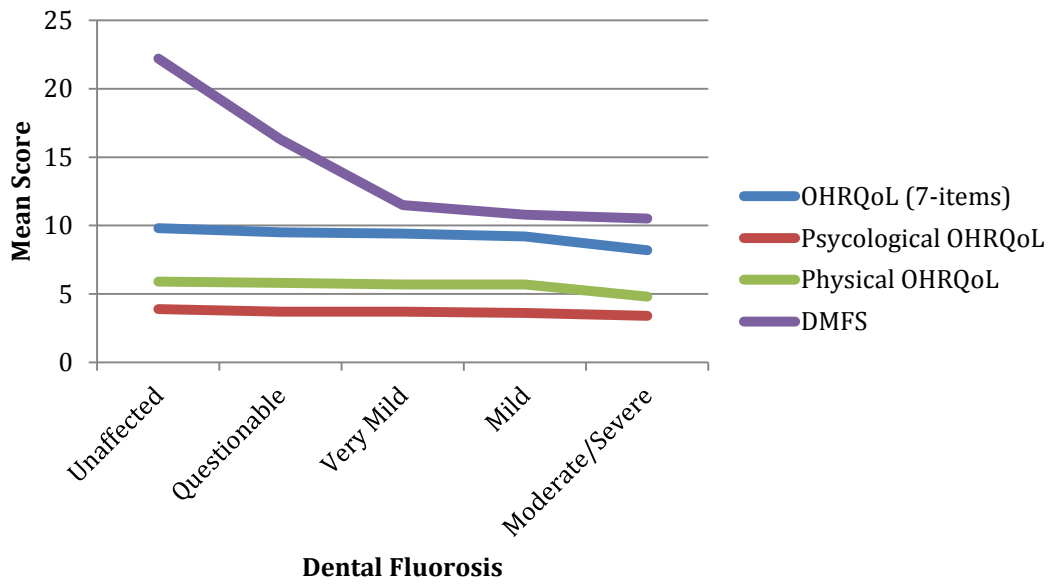
4) How often during last year has your sense of taste been affected by problems with your teeth, mouth, or dentures?

5) How often during last year have you avoided particular food because of problems with your teeth, mouth, or dentures?

6) How often during last year have you found it uncomfortable to eat any food because of problems with your teeth, mouth, or dentures?

(D) All the provided percentages are column percent that are rounded up to the first digit after the decimal.

Figure 28. The association between dental fluorosis and OHRQoL with DMFS for all teeth



iv. LINEAR REGRESSION MODEL ON THE ASSOCIATION
BETWEEN MEAN OHRQoL AND DENTAL FLUOROSIS,
CONTROLLING FOR CONFOUNDING

This linear regression model takes into account the association of all variables simultaneously. After controlling of DMFS and other covariates in the model, fluorosis severity was no longer significantly associated with lower OHRQoL score (except for moderate/severe category). In regard to race/ethnicity, when compared to Non-Hispanic Whites, Mexican Americans ($\beta=-0.8$, $p\text{-value}=0.002$), in addition to others ($\beta=-0.7$, $p\text{-value}=0.01$), have significant lower OHRQoL. Gender and education level were insignificant factors in the relationship with OHRQoL after controlling for all covariates. People with high income status (at or above 200% FPL) had significant decrease in OHRQoL ($\beta=-0.9$, $p\text{-value}=0.001$), when compared to those living with low poverty status (below 100% FPL). DMFS is statistically significant ($\beta=0.02$, $p\text{-value}<0.0001$). In regard to dental behaviors, participants whose time since last dental visit was in 1 to 5 years had significant lower OHRQoL score denoting better OHRQoL ($\beta=-0.6$, $p\text{-value}=0.01$) when compared to participants whose time since last dental visit was in less than 12 months. Participants whose last dental visit reason was for treatment had higher OHRQoL score denoting worse OHRQoL ($\beta=2.0$, $p\text{-value}=<0.0001$) when compared to participants whose last dental visit reason was for checkup, examination or cleaning.

| Table 10: Multivariable linear regression model to predict the association between mean OHRQoL, as a dependent variable, and dental fluorosis as a main predictor, controlling for other factors (2003-2004) | | |
|---|-------------------|----------------|
| | 2003-2004 | |
| | B-estimate | P-value |
| Intercept | 8.7 | <0.0001 |
| Dental Fluorosis | | |
| Unaffected | Reference | |
| Questionable | 0.1 | 0.7 |
| Very mild | 0.1 | 0.6 |
| Mild | 0.2 | 0.6 |
| Moderate/ Severe | -0.6 | 0.05 |
| Age | | |
| 16-19 years | Reference | |
| 20-29 years | 0.3 | 0.1 |
| 30-29 years | 0.3 | 0.2 |
| 40-49 years | 0.1 | 0.7 |
| Gender | | |
| Males | Reference | |
| Females | 0.3 | 0.1 |
| Race/ethnicity | | |
| Non-Hispanic Whites | Reference | |
| Non-Hispanic Blacks | -0.1 | 0.5 |
| Mexican Americans | -0.8 | 0.002 |
| Other race | -0.7 | 0.01 |
| Education | | |
| Less than high school | Reference | |
| High school graduate | -0.3 | 0.4 |
| More than high school | -0.4 | 0.2 |
| Poverty Status | | |
| Low (<100% FPL) | Reference | |
| Medium (100%-199% FPL) | -0.4 | 0.08 |
| High (>=200% FPL) | -0.9 | 0.001 |
| DMFS | 0.02 | <0.0001 |

| | | |
|-------------------------------------|-----------|---------|
| Time since last dental visit | | |
| <12 months | Reference | |
| 1-5 years | -0.6 | 0.01 |
| >5 years, never | 0.2 | 0.7 |
| Reason of last dental visit | | |
| Checkup, examination, or cleaning | Reference | |
| Treatment | 2.0 | <0.0001 |
| Other | 1.7 | 0.002 |

** Negative β estimates denote better OHRQoL, as lower OHRQoL scores mean better perception, and vice versa. ($R^2=0.13$)*

c. THE INFLUENCE OF DENTAL FLUOROSIS ON THE OHRQoL

ITEM BY ITEM

In order to investigate the effect of dental fluorosis on OHRQoL item-by-item, logistic regression analysis was performed. The outcome, which is OHRQoL responses [never, hardly ever, occasionally and often), was binary (no/yes), where “no” was the combination of “never” and “hardly ever” responses and “yes” was the combination of “occasionally” and “often”. The outcome of interest was “yes” and the main predictor was dental fluorosis experience. The generated models are accounted for confounding that may occur from age, gender, race/ethnicity, education level, income and DMFS.

The results show that moderate/severe dental fluorosis experience has statistical significant effect on four OHRQoL questions. People aged 16-49 with moderate/severe fluorosis had 0.2 times the odds of having painful aching in the mouth compared to people of the same age group with no fluorosis, controlled for age, gender, race/ethnicity, education, income and caries experience. In addition, people of the same age group with moderate/severe fluorosis had 0.1 times the odds of having less satisfying life compared to people of the same age group with no fluorosis, controlled for confounding. Moreover, those people aged 16-49 with moderate/severe fluorosis had 0.2 times the odds of having difficulties doing their usual jobs or attending school because of problems with teeth, mouth or dentures, compared to people of the same age group with no fluorosis, and they also had 0.3 times the odds of being uncomfortable to eat any food because of problems with teeth, mouth or dentures compared to people of the same age group with no

fluorosis, controlled for age, gender, race/ethnicity, education, income and caries experience.

| Table 11-1 | | | |
|--|-----------------------------|------------------------------|-----|
| Multivariable logistic regression model to predict the association between OHRQoL item “How often during last year have you had painful aching anywhere in your mouth?” as a dependent variable, and dental fluorosis as a main predictor | | | |
| Dental Fluorosis | Odds Ratio Estimates | 95% Confidence limits | |
| Unaffected | Reference | | |
| Questionable | 1.2 | 0.8 | 1.6 |
| Very Mild | 1.0 | 0.8 | 1.4 |
| Mild | 1.2 | 0.6 | 2.3 |
| Moderate/Severe | 0.2 | 0.1 | 0.5 |

The model is accounted for age, gender, race/ethnicity, education, income and DMFS (c=0.6).

| Table 11-2 | | | |
|---|-----------------------------|------------------------------|-----|
| Multivariable logistic regression model to predict the association between OHRQoL item “How often during last year have you felt life in general was less satisfying because of problems with your teeth, mouth, or dentures?” as a dependent variable, and dental fluorosis as a main predictor | | | |
| Dental Fluorosis | Odds Ratio Estimates | 95% Confidence limits | |
| Unaffected | Reference | | |
| Questionable | 0.9 | 0.6 | 1.5 |
| Very Mild | 1.2 | 0.6 | 2.2 |
| Mild | 1.1 | 0.4 | 2.9 |
| Moderate/Severe | 0.1 | 0.1 | 0.4 |

The model is accounted for age, gender, race/ethnicity, education, income and DMFS (c=0.7).

| Table 11-3 | | | |
|--|-----------------------------|------------------------------|-----|
| Multivariable logistic regression model to predict the association between OHRQoL item “How often during last year have you had difficulty doing your usual jobs or attending school because of problems with teeth, mouth, or dentures?” as a dependent variable, and dental fluorosis as a main predictor | | | |
| Dental Fluorosis | Odds Ratio Estimates | 95% Confidence limits | |
| Unaffected | Reference | | |
| Questionable | 1.0 | 0.7 | 1.7 |
| Very Mild | 0.7 | 0.3 | 1.9 |
| Mild | 1.5 | 0.4 | 5.8 |
| Moderate/Severe | 0.2 | 0.4 | 0.7 |

- The model is accounted for age, gender, race/ethnicity, education, income and DMFS (c=0.7)

| Table 11-4 | | | |
|---|-----------------------------|------------------------------|-----|
| Multivariable logistic regression model to predict the association between OHRQoL item “How often during last year has your sense of taste been affected by problems with your teeth, mouth, or dentures?” as a dependent variable, and dental fluorosis as a main predictor | | | |
| Dental Fluorosis | Odds Ratio Estimates | 95% Confidence limits | |
| Unaffected | Reference | | |
| Questionable | 0.7 | 0.4 | 1.2 |
| Very Mild | 0.8 | 0.4 | 1.5 |
| Mild | 1.2 | 0.3 | 4.8 |
| Moderate/Severe | 1.1 | 0.3 | 4.0 |

The model is accounted for age, gender, race/ethnicity, education, income and DMFS (c=0.7).

| Table 11-5 | | | |
|--|-----------------------------|------------------------------|-----|
| Multivariable logistic regression model to predict the association between OHRQoL item “How often during last year have you avoided particular food because of problems with your teeth, mouth, or dentures?” as a dependent variable, and dental fluorosis as a main predictor | | | |
| Dental Fluorosis | Odds Ratio Estimates | 95% Confidence limits | |
| Unaffected | Reference | | |
| Questionable | 0.9 | 0.7 | 1.3 |
| Very Mild | 0.9 | 0.6 | 1.3 |
| Mild | 1.3 | 0.7 | 2.4 |
| Moderate/Severe | 0.7 | 0.2 | 2.5 |

The model is accounted for age, gender, race/ethnicity, education, income and DMFS (c=0.6).

| Table 11-6 | | | |
|---|-----------------------------|------------------------------|-----|
| Multivariable logistic regression model to predict the association between OHRQoL item “How often during last year have you found it uncomfortable to eat any food because of problems with your teeth, mouth, or dentures?” as a dependent variable, and dental fluorosis as a main predictor | | | |
| Dental Fluorosis | Odds Ratio Estimates | 95% Confidence limits | |
| Unaffected | Reference | | |
| Questionable | 0.8 | 0.7 | 1.0 |
| Very Mild | 0.8 | 0.6 | 1.1 |
| Mild | 1.0 | 0.5 | 2.3 |
| Moderate/Severe | 0.3 | 0.1 | 0.7 |

The model is accounted for age, gender, race/ethnicity, education, income and DMFS(c=0.6).

Table 11-7

Multivariable logistic regression model to predict the association between OHRQoL item “How often during last year have you been self-conscious or embarrassed because of your teeth, mouth, or dentures?” as a dependent variable, and dental fluorosis as a main predictor

| Dental Fluorosis | Odds Ratio Estimates | 95% Confidence limits | |
|-------------------------|-----------------------------|------------------------------|-----|
| Unaffected | Reference | | |
| Questionable | 1.0 | 0.7 | 1.4 |
| Very Mild | 1.2 | 0.9 | 1.6 |
| Mild | 0.9 | 0.4 | 1.8 |
| Moderate/Severe | 1.3 | 0.5 | 3.4 |

The model is accounted for age, gender, race/ethnicity, education, income and DMFS (c=0.7).

d. THE INFLUENCE OF GENDER AND INCOME ON THE
RELATIONSHIP BETWEEN MEAN OHRQoL, DENTAL FLUOROSIS
AND CARIES

i. GENDER

Additional analysis was done to control for confounding by examining the primary association between dental fluorosis experience, DMFS and OHRQoL at different levels of gender (males vs. females). Stratification gives smaller error in estimation, measurements become more manageable, and it is often desirable to get estimates of population parameters for groups with the population. For this analysis, the outcome is the continuous measure of OHRQoL. Dental fluorosis experience is categorized into three categories: normal + questionable, very mild + mild, and moderate + severe. Dental caries was measured by DMFS and categorized into four categories: 0, 1-20, 21-49, and ≥ 50 .

Table 12 (1&2) shows the OHRQoL least square mean scores according to its association with dental fluorosis and DMFS by gender. In males and females, the relationship between OHRQoL and dental fluorosis is inversely proportional (i.e. as fluorosis severity increases, the OHRQoL score decreases denoting better OHRQoL). However, this relationship is not statistically significant. Regarding dental caries, the association between OHRQoL and DMFS is significantly linearly proportional in males and females (except in females when DMFS score ranges between 1-20). This means that when DMFS score increases, OHRQoL score increases too denoting worse OHRQoL.

| Table12-1: The OHRQoL least square mean scores according to the association between OHRQoL and dental fluorosis by gender - all teeth analysis. | | | |
|--|------------------------------|-------------------------|--------------------------|
| Gender/dental fluorosis (P-values) | Normal + Questionable | Very Mild + Mild | Moderate + Severe |
| "Males" | 9.7 | 10.0 (0.4) | 8.9 (0.3) |
| "Females" | 10.2 | 10.0 (0.8) | 9.1 (0.3) |

*Least squares means for the effect of dental fluorosis on the OHRQoL, according to gender, generated by two-factor ANOVA with Tukey-Kramer multiple comparisons test. Lower least square means denote better OHRQoL and vice versa.

| Table12-2: The OHRQoL least square mean scores according to the association between OHRQoL and dental caries, by gender - all teeth analysis. | | | | |
|--|---------------|------------------|-------------------|--------------------|
| Gender/dental caries (P-values) | DMFS=0 | DMFS=1-20 | DMFS=21-49 | DMFS>=50 |
| "Males" | 8.2 | 9.0 (0.02) | 9.1 (0.008) | 11.8 (<0.0001) |
| "Females" | 8.5 | 8.9 (0.7) | 9.9 (0.002) | 11.7 (<0.0001) |

*Least squares means for the effect of dental caries on the OHRQoL, according to gender, generated by two-factor ANOVA with Tukey-Kramer multiple comparisons test. Lower least square means denote better OHRQoL and vice versa.

The interaction between OHRQoL with dental fluorosis and caries in males is shown in figure 30, in which OHRQoL mean score is clearly not affected by dental fluorosis severity, however, it is affected by dental caries by having higher OHRQoL mean scores with higher DMFS scores (mostly DMFS>=50) denoting worse quality of life. Figure 31 is showing the interaction between OHRQoL with dental fluorosis and caries in females, in which again OHRQoL is not affected by dental fluorosis severity but it is affected by dental caries by having higher OHRQoL mean scores with higher DMFS scores.

Figure 29. The interaction between OHRQoL, dental fluorosis and dental caries - Males

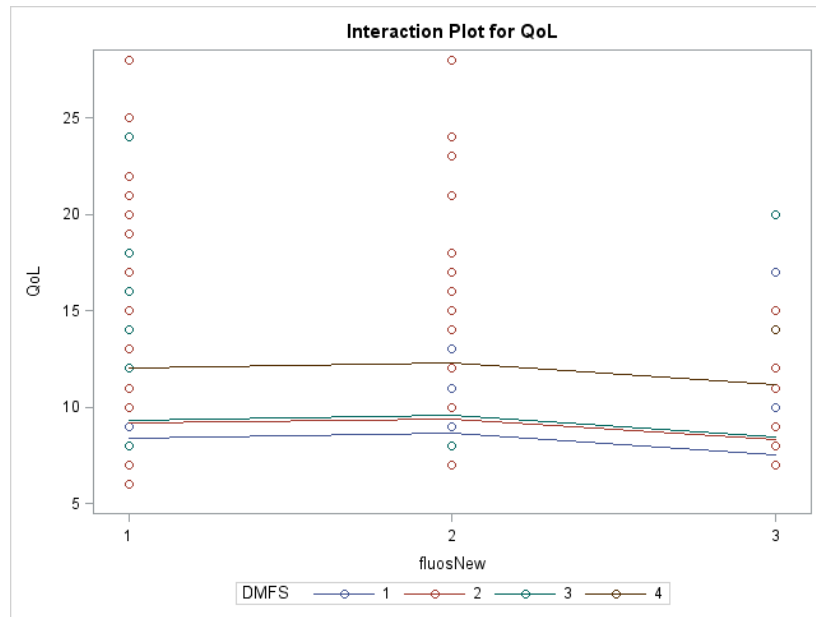
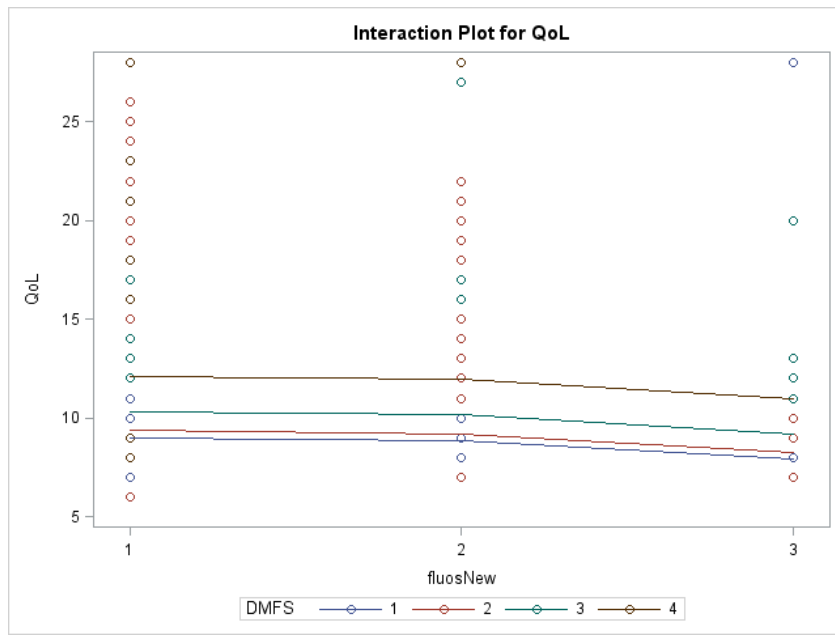


Figure 30. The interaction between OHRQoL, dental fluorosis and dental caries - Females



ii. BY POVERTY STATUS

Stratified analysis by poverty status was done to determine the association between OHRQoL with dental fluorosis and DMFS. Poverty status is categorized into three categories: low (<100% FPL), medium (100-199% FPL) and high (>=200% FPL).

Table 13 (1&2) shows the OHRQoL least square mean scores according to its association with dental fluorosis and DMFS by poverty status. The relationship between OHRQoL and dental fluorosis is inversely proportional (i.e. as fluorosis severity increases, the OHRQoL score decreases denoting better OHRQoL). However, this relationship is not statistically significant. Regarding dental caries, the association between OHRQoL and DMFS is linearly proportional, meaning that when DMFS score increases, OHRQoL score increases also, denoting worse OHRQoL. This relationship is statistically significant when DMFS score is >=50 and when DMFS score is 21-49 in people with low or high poverty status.

| Table13-1: The OHRQoL least square mean scores according to the association between OHRQoL, and dental fluorosis, by poverty status - all teeth analysis. | | | |
|--|------------------------------|-------------------------|--------------------------|
| Poverty status/ fluorosis (P-values) | Normal + Questionable | Very Mild + Mild | Moderate + Severe |
| “Low (<100% FPL)” | 11.1 | 10.6 (0.3) | 9.7 (0.4) |
| “Medium (100%-199% FPL)” | 10.2 | 10.0 (0.8) | 10.1 (1.0) |
| “High (>=200% FPL)” | 9.5 | 9.8 (0.2) | 8.4 (0.2) |

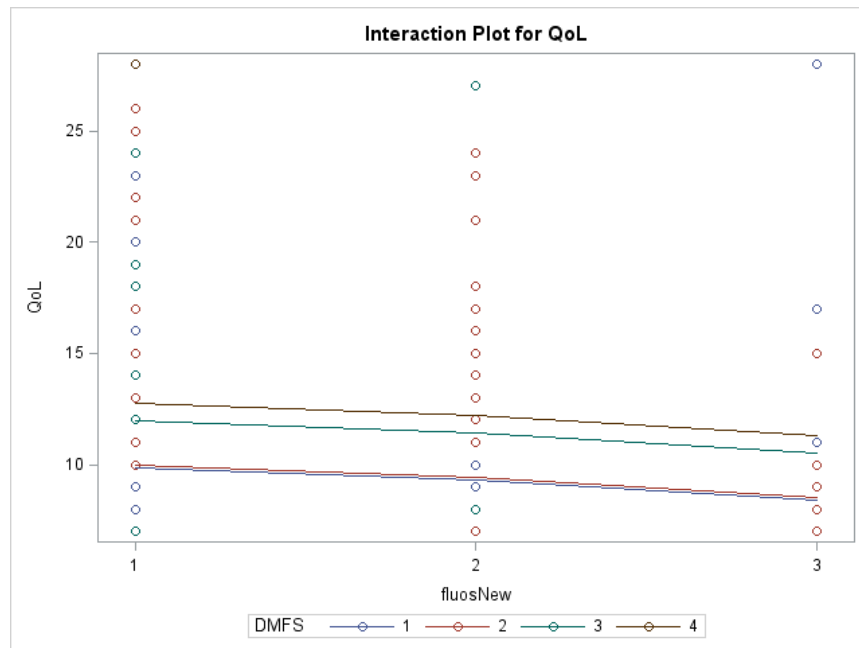
*Least squares means for the effect of dental fluorosis on the OHRQoL, according to poverty status, generated by two-factor ANOVA with Tukey-Kramer multiple comparisons test. Lower least square means denote better OHRQoL and vice versa.

| Table13-2: The OHRQoL least square mean scores according to the association between OHRQoL, and dental caries, by poverty status - all teeth analysis. | | | | |
|---|---------------|------------------|-------------------|--------------------|
| Poverty status/dental caries (P-values) | DMFS=0 | DMFS=1-20 | DMFS=21-49 | DMFS>=50 |
| “Low (<100% FPL)” | 9.2 | 9.3 (0.996) | 11.3 (0.001) | 12.1 (0.001) |
| “Medium (100%-199% FPL)” | 9.0 | 9.7 (0.40) | 10.0 (0.24) | 11.8 (0.0002) |
| “High (>=200% FPL)” | 7.9 | 8.6 (0.07) | 9.1 (0.001) | 11.4 (<0.0001) |

*Least squares means for the effect of dental fluorosis on the OHRQoL, according to poverty status, generated by two-factor ANOVA with Tukey-Kramer multiple comparisons test. Lower least square means denote better OHRQoL and vice versa.

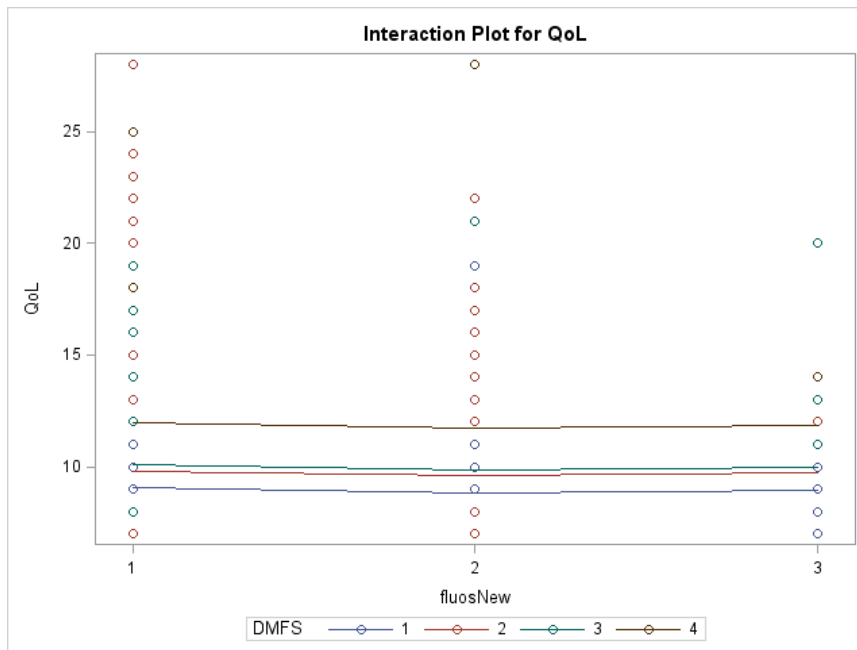
The interaction between OHRQoL with dental fluorosis and caries in people with low poverty status (<100% FPL) is shown in figure 32, in which OHRQoL mean score is mainly affected by dental caries by having higher OHRQoL mean scores with higher DMFS scores (mostly DMFS \geq 50) denoting worse quality of life, and to lesser extent by dental fluorosis severity, in which having moderate/severe fluorosis is associated with lower OHRQoL mean scores denoting better OHRQoL.

Figure 31. The interaction between OHRQoL, dental fluorosis and dental caries - in people with low poverty status <100% FPL



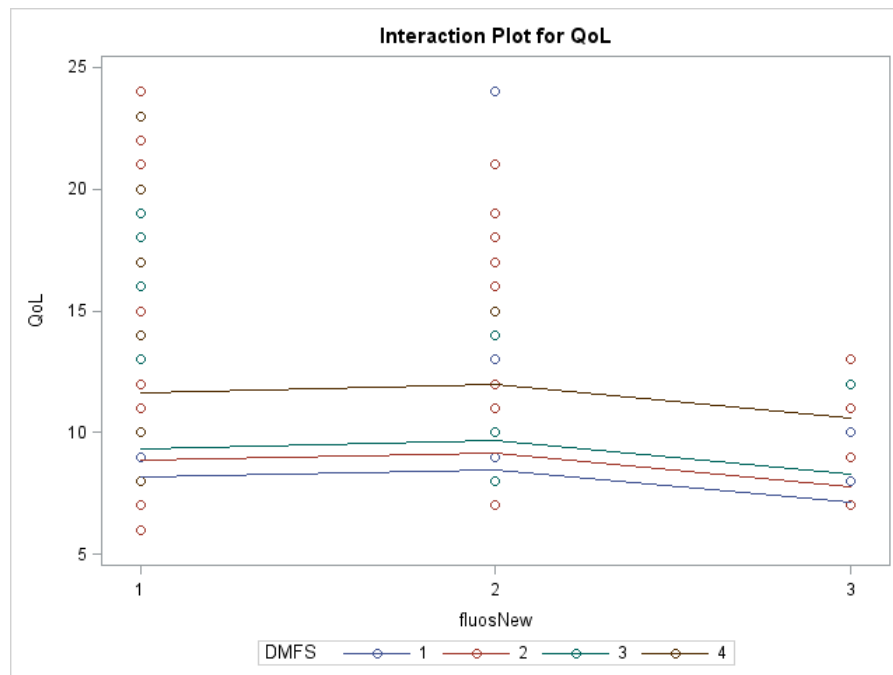
The interaction between OHRQoL with dental fluorosis and caries in people with medium poverty status (100-199% FPL) is shown in figure 33, in which OHRQoL mean score is not affected by dental fluorosis severity, however, it is affected by dental caries (mostly DMFS \geq 50) where having higher DMFS score is associated with higher OHRQoL mean scores denoting worse quality of life.

Figure 32. The interaction between OHRQoL, dental fluorosis and dental caries - in people with medium poverty status (100%-199% FPL)



The interaction between OHRQoL with dental fluorosis and caries in people with high poverty status ($\geq 200\%$ FPL) is shown in figure 34, in which OHRQoL mean score is mainly affected by dental caries by having higher OHRQoL mean scores with higher DMFS scores (mostly $DMFS \geq 50$) denoting worse quality of life. OHRQoL mean score is also affected by dental fluorosis severity to a lesser extent, in which having moderate/severe fluorosis is associated with lower OHRQoL mean scores denoting better OHRQoL.

Figure 33. The interaction between OHRQoL, dental fluorosis and dental caries - in people with high poverty status $\geq 200\%$ FPL



e. **ANTERIOR TEETH ONLY ANALYSIS**

i. **LINEAR REGRESSION MODEL ON THE ASSOCIATION**
BETWEEN MEAN OHRQoL AND DENTAL FLUOROSIS,
CONTROLLING FOR CONFOUNDING

Dental fluorosis is an esthetic problem and it might affect OHRQoL measures differently depending on the affected teeth (all teeth vs. anterior teeth). Therefore, we conducted some analyses on anterior teeth only to show dental fluorosis' influence on quality of life in children and adolescents. Table 14 demonstrates the linear regression model taking into account the association of all variables simultaneously. After controlling of DMFS and other covariates in this model, fluorosis severity was no longer significantly associated with lower OHRQoL score, except for moderate/severe category (B -estimate=-1.0, p -value=0.03) in which it is associated with lower scores of OHRQoL denoting better perception of quality of life. Differences in age categories in regard to OHRQoL mean score were not statistically significant. In regard to race/ethnicity, when compared to Non-Hispanic Whites, Mexican Americans (β =-0.8, p -value=0.002), in addition to other races (β =-0.7, p -value=0.01), had significant lower OHRQoL mean score denoting better OHRQoL. Gender and education level were insignificant factors in the relationship with OHRQoL after controlling for all covariates. People with high-income level (at or above 200% FPL) had significant decrease in OHRQoL (β =-0.9, p -value=0.001), when compared to those living with low poverty status (below 100% FPL). DMFS is statistically significant (β =0.1, p -value=0.0002) in this model. In regard to dental behaviors, participants whose time since last dental visit was in 1 to 5 years had

significant lower OHRQoL mean score ($\beta=-0.6$, $p\text{-value}=0.006$) when compared to participants whose time since last dental visit was in less than 12 months. Participants whose last dental visit reason was for treatment had higher OHRQoL score denoting worse OHRQoL ($\beta=2.0$, $p\text{-value}=\leq 0.0001$) when compared to participants whose last dental visit reason was for checkup, examination or cleaning.

| Table 14: Multivariable linear regression model to predict the association between mean OHRQoL, as a dependent variable, and dental fluorosis as a main predictor, controlling for other factors (2003-2004) | | |
|---|-------------------|----------------|
| | 2003-2004 | |
| | B-estimate | P-value |
| Intercept | 8.8 | <0.0001 |
| Dental Fluorosis | | |
| Unaffected | Reference | |
| Questionable | 0.2 | 0.4 |
| Very mild | 0.1 | 0.7 |
| Mild | 0.2 | 0.7 |
| Moderate/ Severe | -1.0 | 0.03 |
| Age | | |
| 16-19 years | Reference | |
| 20-29 years | 0.4 | 0.08 |
| 30-29 years | 0.5 | 0.08 |
| 40-49 years | 0.4 | 0.3 |
| Gender | | |
| Males | Reference | |
| Females | 0.4 | 0.1 |
| Race/ethnicity | | |
| Non-Hispanic Whites | Reference | |
| Non-Hispanic Blacks | -0.1 | 0.6 |
| Mexican Americans | -0.8 | 0.002 |
| Other race | -0.7 | 0.01 |
| Education | | |
| Less than high school | Reference | |
| High school graduate | -0.2 | 0.5 |
| More than high school | -0.3 | 0.3 |
| Poverty Status | | |
| Low (<100% FPL) | Reference | |
| Medium (100%-199% FPL) | -0.5 | 0.05 |
| High (>=200% FPL) | -0.9 | 0.001 |
| DMFS | 0.1 | 0.0002 |

| | | |
|-------------------------------------|-----------|---------|
| Time since last dental visit | | |
| <12 months | Reference | |
| 1-5 years | -0.6 | 0.006 |
| >5 years, never | 0.1 | 0.8 |
| Reason of last dental visit | | |
| Checkup, examination, or cleaning | Reference | |
| Treatment | 2.1 | <0.0001 |
| Other | 1.7 | 0.002 |

** Negative β estimates denote better OHRQoL, as lower OHRQoL scores mean better perception, and vice versa. ($R^2=0.14$)*

ii. **THE INFLUENCE OF DENTAL FLUOROSIS ON THE OHRQoL
ITEM BY ITEM**

Additional analyses were performed on anterior teeth only to investigate the effect of dental fluorosis on OHRQoL item-by-item. The outcome, which is OHRQoL responses [never, hardly ever, occasionally and often), was binary (no/yes), where “no” was the combination of “never” and “hardly ever” responses and “yes” was the combination of “occasionally” and “often”. The outcome of interest was “yes” and the main predictor was dental fluorosis experience. The generated models are accounted for confounding that may occur from age, gender, race/ethnicity, education level, income and DMFS.

The results show that moderate/severe dental fluorosis experience has statistical significant effect on three OHRQoL questions. People aged 16-49 with moderate/severe fluorosis had 0.1 times the odds of having painful aching in the mouth compared to people of the same age group with no fluorosis, controlled for age, gender, race/ethnicity, education, income and caries experience. In addition, people aged 16-49 with mild fluorosis had 4.7 times the odds of altered taste because of problems with teeth, mouth or dentures compared to people of the same age group with no fluorosis, controlled for the mentioned covariates. Moreover, people with moderate/severe fluorosis had 0.2 times the odds of being uncomfortable to eat any food because of problems in teeth, mouth or dentures compared to people of the same age group with no fluorosis, controlled for confounding.

| Table 15-1 | | | |
|--|-----------------------------|------------------------------|-----|
| Multivariable logistic regression model to predict the association between OHRQoL item “How often during last year have you had painful aching anywhere in your mouth?” as a dependent variable, and dental fluorosis as a main predictor | | | |
| Dental Fluorosis | Odds Ratio Estimates | 95% Confidence limits | |
| Unaffected | Reference | | |
| Questionable | 1.0 | 0.8 | 1.3 |
| Very Mild | 1.0 | 0.7 | 1.4 |
| Mild | 0.5 | 0.2 | 1.5 |
| Moderate/Severe | 0.1 | 0.01 | 0.3 |

The model is accounted for age, gender, race/ethnicity, education, income and DMFS (c=0.6).

| Table 15-2 | | | |
|---|-----------------------------|------------------------------|-----|
| Multivariable logistic regression model to predict the association between OHRQoL item “How often during last year have you felt life in general was less satisfying because of problems with your teeth, mouth, or dentures?” as a dependent variable, and dental fluorosis as a main predictor | | | |
| Dental Fluorosis | Odds Ratio Estimates | 95% Confidence limits | |
| Unaffected | Reference | | |
| Questionable | 1.1 | 0.8 | 1.6 |
| Very Mild | 1.2 | 0.5 | 2.8 |
| Mild | 0.5 | 0.1 | 3.4 |
| Moderate/Severe | 0.2 | 0.1 | 1.1 |

The model is accounted for age, gender, race/ethnicity, education, income and DMFS (c=0.7).

| Table 15-3 | | | |
|--|-----------------------------|------------------------------|-----|
| Multivariable logistic regression model to predict the association between OHRQoL item “How often during last year have you had difficulty doing your usual jobs or attending school because of problems with teeth, mouth, or dentures?” as a dependent variable, and dental fluorosis as a main predictor | | | |
| Dental Fluorosis | Odds Ratio Estimates | 95% Confidence limits | |
| Unaffected | Reference | | |
| Questionable | 0.7 | 0.4 | 1.5 |
| Very Mild | 0.7 | 0.2 | 2.6 |
| Mild | 0.6 | 0.1 | 3.1 |
| Moderate/Severe | 0.2 | 0.02 | 1.4 |

The model is accounted for age, gender, race/ethnicity, education, income and DMFS (c=0.6)

| Table 15-4 | | | |
|---|-----------------------------|------------------------------|------|
| Multivariable logistic regression model to predict the association between OHRQoL item “How often during last year has your sense of taste been affected by problems with your teeth, mouth, or dentures?” as a dependent variable, and dental fluorosis as a main predictor | | | |
| Dental Fluorosis | Odds Ratio Estimates | 95% Confidence limits | |
| Unaffected | Reference | | |
| Questionable | 1.2 | 0.6 | 2.2 |
| Very Mild | 0.7 | 0.3 | 1.9 |
| Mild | 4.7 | 1.3 | 17.5 |
| Moderate/Severe | 0.4 | 0.04 | 3.7 |

The model is accounted for age, gender, race/ethnicity, education, income and DMFS (c=0.7).

| Table 15-5 | | | |
|--|-----------------------------|------------------------------|-----|
| Multivariable logistic regression model to predict the association between OHRQoL item “How often during last year have you avoided particular food because of problems with your teeth, mouth, or dentures?” as a dependent variable, and dental fluorosis as a main predictor | | | |
| Dental Fluorosis | Odds Ratio Estimates | 95% Confidence limits | |
| Unaffected | Reference | | |
| Questionable | 1.0 | 0.7 | 1.5 |
| Very Mild | 1.0 | 0.7 | 1.6 |
| Mild | 1.4 | 0.5 | 4.4 |
| Moderate/Severe | 0.5 | 0.1 | 2.1 |

The model is accounted for age, gender, race/ethnicity, education, income and DMFS (c=0.6).

| Table 15-6 | | | |
|---|-----------------------------|------------------------------|-----|
| Multivariable logistic regression model to predict the association between OHRQoL item “How often during last year have you found it uncomfortable to eat any food because of problems with your teeth, mouth, or dentures?” as a dependent variable, and dental fluorosis as a main predictor | | | |
| Dental Fluorosis | Odds Ratio Estimates | 95% Confidence limits | |
| Unaffected | Reference | | |
| Questionable | 0.8 | 0.6 | 1.1 |
| Very Mild | 0.7 | 0.4 | 1.2 |
| Mild | 1.1 | 0.5 | 2.4 |
| Moderate/Severe | 0.2 | 0.04 | 0.5 |

The model is accounted for age, gender, race/ethnicity, education, income and DMFS(c=0.6).

Table 15-7

Multivariable logistic regression model to predict the association between OHRQoL item “How often during last year have you been self-conscious or embarrassed because of your teeth, mouth, or dentures?” as a dependent variable, and dental fluorosis as a main predictor

| Dental Fluorosis | Odds Ratio Estimates | 95% Confidence limits | |
|-------------------------|-----------------------------|------------------------------|-----|
| Unaffected | Reference | | |
| Questionable | 1.2 | 0.9 | 1.6 |
| Very Mild | 0.8 | 0.5 | 1.4 |
| Mild | 1.3 | 0.5 | 3.2 |
| Moderate/Severe | 0.9 | 0.2 | 3.4 |

The model is accounted for age, gender, race/ethnicity, education, income and DMFS (c=0.7).

CHAPTER V

DISCUSSION

In this study, we compared recent trends in dental fluorosis and caries among children and adolescents aged 6-19 in the United States from 1999-2004 to 2011-2012. It was found that dental fluorosis had increased from 1999-2004 to 2011-2012, particularly in the mild, moderate and severe fluorosis categories among children and adolescents aged 6-19. Our findings may be not directly compared to previous studies due to the different age groups analysis. The reason behind age restriction in our study is that NHANES 2011-2012 performs dental fluorosis examination only to persons aged 6-19. Yet, we estimated the prevalence of dental fluorosis in its milder forms to be 35% among adolescents aged 12-15, which is not of a much difference of what was found in 1999-2004 (37.1%). However, it is still higher than what was found in Dean's study or Heller et al. study regarding dental fluorosis prevalence (11%, 21.3%, respectively).

The National Center for Health Statistics released a report in 2007 about the trends in oral health status in the US, 1988-1994 and 1999-2004 (National Center for Health Statistics, 2007). They found that among children aged 2-5 years, caries experience increased because of the increase in the filled teeth and among children aged 6-11, caries experience in permanent teeth declined and untreated caries was unchanged. In addition, caries experience among adolescents aged 12-19 declined and untreated caries was unchanged. In our study, the percentage of caries experience among people aged 6-19 was unchanged from 1999-2004 to 2011-2012. However, the percentage of untreated caries significantly decreased among people aged 6-19 from 1999-2004 to

2011-2012. Non-Hispanic Blacks and Mexican Americans had increased DMFS scores compared to Non-Hispanic Whites. Moreover, DMFS scores were lower for females, those with more than high school education, those who are living in high Federal Poverty level, those whom last dental visit was in <12 months for treatment. Regarding the prevalence of untreated caries in permanent teeth, it had generally declined among people aged 6-19; however, there was an increase among those who had poor perception about their mouth and teeth and among those who had their last dental visit in >5 years or never.

Over the years, the relationship between dental fluorosis and dental caries had been studied heavily. In the late 1930s, Dean investigated the lowest fluoride level at which dental caries was clearly inhibited. He conducted the “21 cities study” in which he did clinical examinations on children aged 12-14 with lifetime residence in 8 suburban Chicago communities with various but stable mean F levels in their domestic water. The project expanded by adding 13 additional cities in Illinois, Colorado, Ohio and Indiana. The results of this ecological study showed that dental caries experience in different communities was dropped sharply as F concentration rose toward 1 ppm then leveled off. In addition, dental fluorosis experience rose sharply above 1 ppm F concentration. It is important to understand the flaws and limitations of this study. The selected cities varied widely in population size and the included subjects were only Caucasians (*CDC, 1999*). Moreover, the study was prone to examiner bias because the examiners were not blind to the city of residence where they can impose their knowledge of fluoride concentration of the city water supply and other unconscious assumptions may be made. In 1986-87,

Heller and Eklund analyzed the data from the National Survey of US School Children and found that the sharpest decline in dfs and DMFS were associated with increase in water fluoride levels between 0-0.7 ppm F concentration, with little additional decline between 0.7 and 1.2 ppm F concentration among individuals aged 5-17. They concluded that a trade off between caries and fluorosis appears to occur around 0.7-ppm F concentration considering the multiple sources of fluoride intake. Recently, the U.S Public Health Service (PHS) provided recommendations regarding the current optimal fluoride concentration in drinking water in which they concluded that caries prevention and dental fluorosis reduction could be achieved at 0.7 ppm fluoride in drinking water, after taking into consideration all sources of fluoride delivery in fluoridated and non-fluoridated communities (*U.S Public Health Services, 2015*).

In addition to those studies, many other ecological studies were done and confirmed the association between dental fluorosis and dental caries in that dental fluorosis decreases dental caries experience mostly among children (S.M. Szpunar et al., 1988; S.R. Grobler et al., 2001). Although ecological studies are quick, inexpensive and easy to be done since it uses readily available data, it cannot link the exposure to the disease because it uses average exposures. This means that these studies assume that all children are living in similar conditions and that every child drinks the same amount of F water; however, the consumption of F water per child is unknown. The relationship whether children with fluorosis have higher or lower caries experience cannot be made by only looking at residence area, but actually, it is whether they have dental fluorosis or not. Our study overcomes this limitation by looking at the relationship between dental

fluorosis and dental caries at the individual level (i.e. investigating dental caries experience in those who already have dental fluorosis). The results showed that dental fluorosis (measured by Dean Index) was significantly associated with dental caries (mean DMFS score) in NHANES 1999-2004 (p-value=0.05) and NHANES 2011-2012 (p-value=0.03) among people aged 6-19. Those with milder forms of dental fluorosis are associated with lower mean DMFS scores; however, the moderate and severe forms of fluorosis are associated with higher mean DMFS scores. This could be explained in that children and adolescents with moderate/severe fluorosis have porous, pitted, and discolored enamel, which is more prone to fracture and wear resulting in caries (*Den-Besten, 1992*). Also, they have a higher percentage of filled teeth that reflects the higher mean DMFS score. Another issue is misclassification; sometimes it is difficult to differentiate whether the lesions are caused by caries or fluorosis, especially the moderate/severe lesions. Similar results were found in a study that was conducted in Australia on children aged 8-9 (*Do and Spencer, 2009*); they concluded that there was a significant negative association between fluorosis status and dental caries in the permanent dentition. In addition, Lida and Kumar found that permanent maxillary first molars with fluorosis were more resistant to caries compared to molars without fluorosis among children aged 7-17 years of age (*Lida H. and Kumar J., 2009*). Another study was done in Brazil showing consistent results in that dental caries significantly (p-value <0.001) decreases with fluorosis among students aged 12 years old, however it demonstrates only the crude association between the two conditions and they did not control for confounders such as age, gender or SES (*Franzolin SOB et. al., 2010*).

In regard to the comparison of the association between dental fluorosis and caries in NHANES 1999-2004 and NHANES 2011-2012, there was a fluctuation in the results that can be explained in that dental fluorosis data in NHANES 2011-2012 is less stable compared to the data in NHANES 1999-2004, which includes 3-cycles, in terms of sampling in which the sample is not based on fluorosis level and the participants with moderate/ severe forms of fluorosis may be clustered in geographical areas because they are associated with natural fluoride levels. In addition, examiner bias may play a role in this association of interest. Furthermore, our findings showed that children aged 6-11 years with moderate/severe fluorosis had the highest DMFS scores compared to children with other levels of fluorosis. The reason behind this relationship is that those children are having a higher percentage of filled teeth and a lower percentage of decayed teeth compared to other children, which reflects the higher overall caries experience scores measured by DMFS.

To determine the effects of early years of life exposure to fluoride on dental caries, additional analysis was done on children aged 8-9 in NHANES 1999-2004. The multivariable linear regression model showed that the mean DMFS score was increased among children aged 8-9 with no dental fluorosis compared to children of the same age group with dental fluorosis; however, this relationship was not statistically significant (p -value= 0.2), controlling for socio-demographics and dental behavior. In addition, a multivariable logistic regression model illustrates that those children aged 8-9 with no dental fluorosis had 1.3 times the odds of having dental caries ($DMFS > 0$) on permanent teeth compared to children of the same age group with dental fluorosis. Again, this

relationship was not statistically significant. Do and Spencer did similar analysis among Australian children of the same age group that revealed consistent results to our study (Do and Spencer, 2009). Their regression models showed that having fluorosis on permanent incisors was associated with significantly lower severity of caries. In addition, children who did not have dental fluorosis had 2.4 times the odds of having caries on permanent teeth at the age 8-9 years compared with children who had fluorosis.

Our study investigated the impact of dental fluorosis and caries on OHRQoL simultaneously considering each other. Previous studies investigated the relationship between caries and OHRQoL, but only few studies considered both conditions concurrently that showed mixed results. Our findings showed that among people aged 16-49 there was a statistically significant negative relationship between dental fluorosis and OHRQoL. This means that the higher fluorosis severity levels, the better quality of life. The most plausible explanation for that unexpected finding is the reduction in caries experience. This study takes into consideration people's perceptions and satisfactions about their oral health. It was found that there was a statistically significant negative relationship between dental fluorosis and dental caries (i.e. people with high fluorosis severity levels and low caries experience had better scores of OHRQoL). Therefore, using fluorides in its different delivery modalities will help to prevent dental caries and enhance people's OHRQoL, even if dental fluorosis was introduced in its milder forms. Moreover, all anti fluoridation groups are focusing on the risk of dental fluorosis and its esthetics problems; however, by using this study finding it is clearly demonstrated that

people's most concern is lowering their caries experience, which will have a direct effect on their OHRQoL.

Our results were consistent with a study that was conducted in Australia among children aged 8-13 years, which found that dental caries had negative impact on OHRQoL, while mild fluorosis had a positive impact on children's OHRQoL (*Do and Spencer, 2007*). On the other hand, some studies found that dental fluorosis had negative impact on OHRQoL (*Aguilar-Diaz et al., 2011; Li YJ et al., 2014*); others indicate that dental fluorosis had little impact, if any, on OHRQoL (*Onoriobe et al., 2014; Oliveira et al., 2015*). In the literature, it had been shown consistently that dental caries was associated negatively with OHRQoL (*Foster Page et al., 2012; Kramer et al., 2013; Ramos-Jorge et al., 2013; Abanto et al., 2014; Pulache et al., 2015; Mota-Veloso et al., 2015*). However, a pilot study that was done on Swedish 19-years-olds, where the prevalence and incidence of dental caries were very low, showed that caries was not associated with OHRQoL, and the usefulness of OHRQoL in supplementing outcome measurement on caries preventive strategies must be questioned (*Oscarson et al., 2007*).

To summarize the significance of this study, first, it contributes to expanding the knowledge about dental fluorosis, dental caries and OHRQoL, in which specific groups can be targeted for fluorides and community water fluoridation campaigns. Second, the science and literature about the association between dental fluorosis and dental caries will be up-to-date since our associations are following the current context of fluoride. Third, policy makers will understand the benefits of fluorides and people's perception regarding dental fluorosis and its true association with dental caries, which will help in setting

policies and recommendations about fluorides. In addition, to monitor progress towards Health People 2020 objectives in improving the quality of life for all Americans, it is very important to include OHRQoL, which is proven to be valid and reliable, in national surveys. Fourth, clinical practice will enhance the emphasis on fluorides, because of its benefits on dental caries, which in turn will affect OHRQoL positively.

Some limitations of our study need to be considered. First, NHANES represents non-institutionalized US population; thus adults at nursing homes, military and other institutions are not included, so the results will not be applicable or generalizable in that context. Second, this study is a cross-sectional study in which conclusions about causal associations cannot be made. Also, since the data in NHANES is publicly available, the exact addresses and zip codes of the subjects are not included, therefore information about the level of F in drinking water is not provided. It would be more beneficial to have more information about F status. In spite of these limitations, still, the NHANES is one of the most representative and largest public health datasets of the US population. In addition, this study is one of few to determine the association between dental caries and dental fluorosis on the individual level among children and adolescents in the US. Although there was no information in NHANES about F exposure, fluorosis experience recorded by Dean index was a good predictor of previous exposure.

CHAPTER VI

CONCLUSIONS

Overall, based on NHANES 1999-2004 to NHANES 2011-2012, dental fluorosis prevalence is significantly increased among persons aged 6-19, especially for moderate and severe dental fluorosis, whereas the prevalence of untreated decay in permanent teeth is decreased among persons of the same age group. The prevalence of caries experience, including filled and decayed teeth, remained unchanged from 1999-2004 to 2011-2012. Moreover, dental fluorosis in its milder forms is associated with decline in caries experience in both NHANES cycles among persons aged 6-19 years, however, caries experience increased with moderate/severe fluorosis because of the higher percentage of filled teeth.

Contrary to the expectation, higher level of dental fluorosis among persons aged 16-49 years was associated with better OHRQoL measures. This is explained by lower levels of caries experience among those who have higher level of fluorosis. These findings suggest that people's OHRQoL perception is more influenced by dental caries rather than the negative aspects of dental fluorosis. Therefore, this finding also demonstrates evidence that the benefits of fluorides in caries prevention exceed the esthetic impact of dental fluorosis.

Under the context of the new optimal fluoride concentration in drinking water by the U.S Public Health Service (PHS), which is 0.7-mg/L, we need to continue monitoring the trends in dental caries and fluorosis. Also, the influence of these conditions on OHRQoL should be continuously investigated.

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