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DEDICATION

This dissertation is dedicated for improving the well-being of humanity in general and American people, in specific, whose tax-money helped in the completion of this research.

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ABSTRACT

Background

Poor oral health had been associated with increased risk of having systemic diseases and thus mortality. The purpose of this research was to find if dental coverage with health insurance could mitigate the risk of death due to untreated dental caries and periodontitis among working age U.S. adults.

Methods

Data were drawn from NHANES III (1988-1994) and linked to mortality updated till Dec. 31st, 2011. It was restricted to those in the age range of 20-64 years adults. Furthermore, it was restricted to those who had complete data collection on all measures. Unweighted propensity scores were calculated to control for the differential proportion of dental coverage in the population separated by gender. The continuous propensity score obtained was converted into quartiles based on the population distribution of both males and females to ascertain the risk of mortality based on low to high probability of dental coverage. All analyses were weighted and adjusted for complex sampling of NHANES III survey using proc survey procedures in SAS v9.4 for each gender. Andersen's model of health care utilization was used as a basis for the addition of incremental variables in the models.

Results

Nearly 10% deaths among males and 7% among females were observed in our sample. Observed deaths were more in those who had increased number of decayed teeth

and periodontitis. Similarly, those who had dental coverage with health insurance had fewer deaths as compared to those without dental coverage. Multivariate analyses showed that people who have increased number of decayed teeth had a higher risk of mortality in both males and females. Only among females, all the propensity quartiles had a protective effect on the risk of mortality in associations with dental decay in the final model. Periodontitis was linked to higher risk of mortality in simplified analyses and the risk reduced with the introduction of dental insurance and dental insurance propensity score. However, in both dental caries and periodontitis for both males and females, dental insurance remained insignificant in the final (full) model but the propensity score for dental coverage in females only.

Conclusion

The dental coverage was not significant in the full models for both dental caries and periodontitis among males and females. Additionally, we did not have any information available on the depth of dental coverage and out of pocket costs associated with dental coverage. However, we do know that access to preventive and curative dental services is guaranteed by dental coverage, therefore, dental coverage should be a mandatory part of health insurance under Medicaid expansion and health care reforms but with little or no financial contribution in the form of co-payments and deductibles for the customer. It is evident from RAND Health Insurance Experiment that improved oral and dental health was seen among those who had free or nominal financial contribution. In future, national surveys should incorporate in-depth details about dental coverage for both out of pocket costs and treatments provided.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

Oral Health

Good oral health comprises of sound dental and periodontal health. When a person does not care for oral health, it leads to the development of either dental caries or periodontal diseases or both. Dental caries is a chronic disease that occurs due to a localized destruction of susceptible dental hard tissue as a result of the production of acid by-product from bacterial fermentation of dietary carbohydrates (CDC, 2014). Periodontitis is a chronic inflammatory disease caused by infection of the supporting tissues around the teeth (Page, Eke, 2007). Both the diseases occur when the preventive measures like regular tooth brushing and teeth cleaning do not take place either by oneself or/and by the professionals respectively (CDC, 2014).

Dental caries starts with supra-gingival plaque formation that harbors several bacteria that lead to demineralization of tooth structure. Dental caries could lead to inflammation of pulp or peri-apical abscess formation that could lead to bacteremia. There are two types of plaque: supra and sub – gingival plaque. The supra-gingival plaque occurs above the gum level and sub-gingival plaque occurs below the gums. Though the composition of sub-gingival plaque is different from supra-gingival plaque in terms of microbial load, however, it has been linked to several systemic diseases like heart problems, diabetes, stroke, cerebrovascular diseases, and kidney diseases. A meta-

analysis conducted by Li et al. (2000) showed that there are three pathways that could lead to non-oral diseases; (a) through transient bacteremia, (b) through circulation of bacterial toxins, and (c) through immunological injury caused by oral bacteria. Several studies have proposed that bacteremia could lead to various systemic diseases (Li et al., 2000). Some probable relations have been proposed linking oral infections to systemic diseases by the production of inflammatory markers (C-reactive proteins, advanced glycation end product (AGE)-mediated cytokine, tumor necrosis factor (TNF-α), and Interleukins (IL-1)). Having insurance provides access to the preventive and curative dental services that would help not only in retention of teeth but keep good oral health through prevention, early diagnosis and treatment of oral diseases, and patient education, preventing bad oral health and thus mortality.

Prevalence of Dental Caries and Periodontitis

The prevalence of both dental caries and periodontal problems have decreased over the past two decades in U.S. among adults aged 20 years and above (Dye, Tan et al. 2007). In 2008, the prevalence of dental coverage was about 73% for adults below the age of 65 years (Bloom & Cohen, 2010).

The prevalence of overall periodontitis in adults ages 30 years and above was 47% during 2009-2010 NHANES, 8.7% for mild periodontitis, 30% for moderate, and 8.5% for severe periodontitis (Eke, Dye, et al, 2012).

Disparities in Oral Health

Though the prevalence of dental caries had decreased since 1970's, however, disparities still prevail (NIDCR, 2014). Oral health disparities exist for race/ethnicity varied by age, gender, and poverty level (CDCb, 2013). Dental caries tend to be highest

among non-Hispanic Blacks and Mexican Americans while periodontitis tends to be greatest among Mexican Americans and non-Hispanic Blacks (CDCb, 2013). Education is a proxy measure for socioeconomic status and people with less education tend to have poor oral health outcomes (CDCb, 2013).

One of the objectives of Healthy people 2020 is to reduce oral health disparities. About one-third of people aged 65 years and above, and living below the federal poverty level (FPL) are edentulous while about one-eighth of those living above the FPL are edentulous. Tooth retention varies by age, 53% of adults within ages 25-44 years and 25% aged 45-64 years had a complete set of teeth. People aged below 65 years and living at or below the FPL constitute a higher proportion of people (58%) who have lost a permanent tooth as compared to those living above the FPL (45%). Among different races, whites tend to retain complete set of teeth than any other races. (Dye, Li, & Thornton-Evans, 2012).

Dental Insurance

Dental insurance is an indicator for primary access to dentists (Bloom & Cohen, 2010). Dental insurance is mostly offered through private insurance companies as the federal and state programs offer limited or no dental programs for adults aged 21 years and above, e.g. in case of Medicaid, it is state dependent and the reimbursement rate is usually very low, if offered (Bloom & Cohen, 2010; Singhal et al., 2015). Medicare only offers limited dental services that are deemed medically necessary, e.g. prior to radiotherapy or surgical reconstruction of the jaw (Vargas et al., 2001; CMS, 2013).

The prevalence of some sort of dental insurance in 2008 was 73% among people below the age of 65 years (Bloom & Cohen, 2010). Having dental insurance leads to

improved oral health as could be seen in the RAND health insurance experiment (Brook et al. 2006). There was an overall increase in use of dental services with generous dental plans having minimum co-insurance (Brook et al. 2006). If an individual is deprived of dental insurance due to any reason, the oral health will deteriorate and will give rise to oral and other systemic diseases. Eliminating Medicaid dental benefits led to increase both in emergency room (ER) visits and the cost of dental ER visits in California in the latter two years of policy change (Singhal et al., 2015).

Role of Dental Coverage & its Elasticity to Co-pay

The relation between cost-sharing plans and total medical expenditure is not linear, therefore, assigning a fixed value (as was done in RAND HIE) to estimate the total healthcare expenditure will not return correct estimates for health insurance plans for customers (Aron-Dine et al., 2013). People while purchasing health insurance plans not only take into account non-linear budget set for expected end of year price but co-insurance as well, which affects their visits to healthcare providers. According to Gupta & Polsky (2015), cost-sharing did not develop customer sophistication, therefore, the customers of health insurance, who participated in RAND HIE, did not become selective in their healthcare decision making.

Private dental coverage increased from 2% to 38% from 1967 to 1981 respectively as a result of employee fringe benefits (Manning et al., 1985). There was a significant increase in utilization of dental services, in terms of dollars or dental visits, during the first year of dental insurance as compared to the second year. Utilization increases with the no/minimum cost sharing, there were 34% more visits and 46% more expenses in the free plan as compared to 95% co-pay plans, causing free plans to have the

highest number of expenditures. Increased income leads to increased use on any dental service; low income in the free plan had more visits as compared to 95% plan. Overall, high income had 26% more visits than low income and was less sensitive to cost sharing.

Freeman et al. (2008) conducted a meta-analysis on health insurance to find out the causal relationship between health insurance and health outcomes. The authors had the following conclusion:

- Health insurance had a significant effect on the use of preventive and physician services, self-reported health status, and deaths due to diseases.
- Cost sharing (co-pay and deductibles) reduced the receipt of preventive and medical services with little or no effect on health outcomes.
- The health insurance plans varied by cost-sharing, depth of coverage, and financial incentives to physicians; but health insurance is measured in dichotomous measures irrespective of the above factors.
- The following were the benefits of having health insurance:
    - Less likely to delay care
    - Less likely to receive care for ambulatory care sensitive conditions
    - Less likely to receive care from emergency department or outpatient clinics
    - Shorter wait times
    - Comprehensive care for chronic conditions
    - Less progressed disease

Oral Health, Systemic Diseases, and Deaths

Healthy People 2010 called oral health a silent epidemic that not only affects the mouth but the whole body (Benjamin, 2010). Poor oral health is known to be associated with morbidities and in some cases mortality, however, there is scarce evidence for the association of dental caries, a subset of oral health problems, with mortality.

Most studies studying the relation between oral health and systemic outcomes (mostly cardiovascular diseases) have focused on periodontal disease (Li et al., 2000; Meurman et al., 2004). Johnston and Vieira (2014) measured dental caries in terms of Decayed, Missing, Filled Teeth/Surfaces (DMFT/DMFS) and reported it to be associated with self-reported systemic diseases like hepatitis, asthma, blood pressure, stroke, liver disease, and diabetes. Previously, poor oral health had been defined as a combination of dental caries, dental biofilm, and periodontitis (Jansson et al., 2002; Jansson et al., 2001); or the number of teeth and/or number of teeth with clinical periodontal attachment loss (Awano et al., 2008); and number of teeth, root caries, and periodontitis (Kim et al., 2013). The relationship between solely dental caries and death remains to be explored.

The relationship between poor oral health/hygiene and death is well established (Navazesh & Mulligan, 1995; Jansson et al., 2002). Kim et al. (2013) conducted a study to see the effects of poor oral health, measured in 3 composite dichotomous indicators: loss of 15 or more teeth, root caries presence, and periodontitis, on deaths using the NHANES 1999-2004 datasets linking with mortality. People with poor oral health aged 40 years and above had higher odds of dying with systemic diseases. Periodontitis is known to cause cardio-vascular diseases (endocarditis, bacterial myocarditis, and blood pressure), diabetes, adverse birth outcomes, cerebro-vascular diseases (brain abscess,

stroke, cavernous sinus thrombosis, and cerebral infarction), renal diseases, respiratory diseases (bacterial pneumonia, lung abscess, sinusitis, and sore throat), Ludwig's angina, orbital cellulitis, osteomyelitis, and joint infection.

Research Questions & Hypotheses

Though the bacterial composition of dental plaque that causes dental caries and periodontitis differs from each other (Mager et al., 2003), however, the bacterial profile has not been completely identified both in sound oral cavity and diseased one. Aas et al. (2005) conducted a study where they found that both cultivable and non-cultivable bacteria exist in healthy mouth and stated the need to conduct further studies to identify non-cultivable bacteria in diseased mouth. Therefore, for this study we regard dental plaque (biofilm) as the common factor for both the dental caries and periodontitis to see the association with mortality. As the underlying causes for both periodontitis and dental caries are similar and mediated by dental plaque, therefore, it is assumed that both dental caries and periodontitis might have a relationship with mortality in the absence of dental insurance. Absence of dental insurance translates in to limited access to both preventive and curative dental services, resulting in delaying dental problems leading to advanced stage of dental diseases causing high number of bacteria in the oral cavity that leads to bacteremia, eventually resulting in systemic diseases, and thus mortality.

The purpose of this study is to examine the effect of private dental coverage on the risk of mortality among males and females with untreated dental caries and periodontitis.

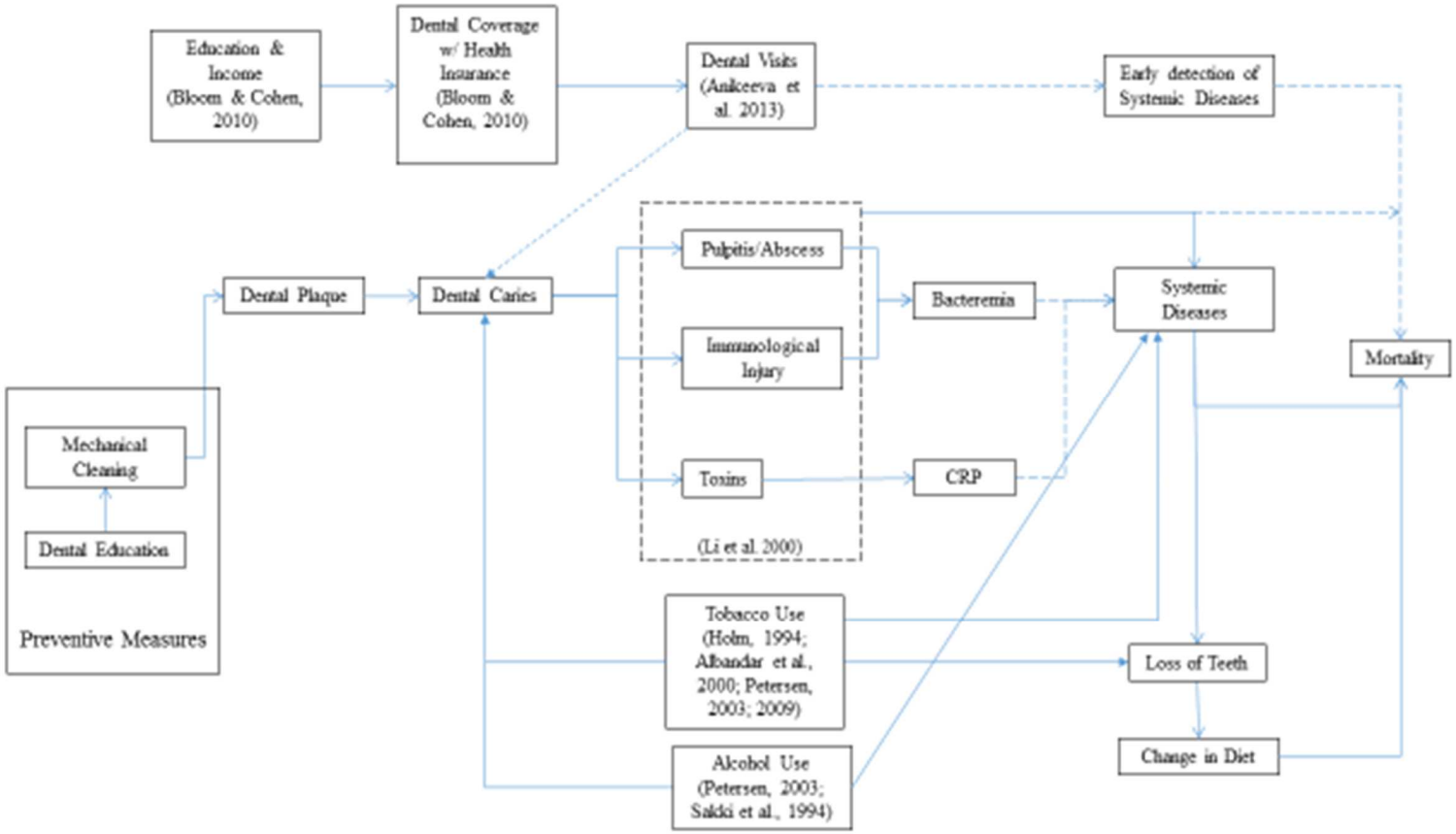

Figure 1.1 Theoretical Framework for the Association between Dental Caries/Periodontitis & Mortality

RQ1: To assess the mitigating effect of private dental coverage with private health insurance on the risk of all-cause mortality among males and females with untreated dental decay.

H1: The risk of death will be greater in people with high number of untreated decayed teeth than those with no untreated decayed teeth.

RQ2: To determine the difference in survival among people with private dental insurance having periodontal diseases controlling for co-morbidities.

H1: The death rate will be less among those with private dental coverage, who have periodontitis.

CHAPTER 2

LITERATURE REVIEW

Dental caries and periodontitis have a shared causal factor, dental plaque. Dental plaque immediately forms on the surface of teeth after tooth brushing. Its bacterial composition significantly differs from healthy mouth to diseased mouth. There are two types of plaques that are formed in the oral cavity; supra-gingival plaque and sub-gingival plaque. The bacterial composition of both the supra and sub gingival plaque also differs from each other. The supra-gingival plaque is formed on the teeth surfaces while sub-gingival on the gingiva surrounding the teeth. Streptococcus mutans and lactobacillus species (Selwitz et al., 2007) had been found to be the culprits for dental caries while Porphyromonas gingivalis, Prevotella intermedia, Actinobacillus actinomycetemcomitans, and Treponema species had been associated with periodontitis (Socransky et al., 1998; Tatakis & Kumar, 2005). However, new laboratory analytical techniques have enabled scientists to detect non-cultivable microbiota present in both the conditions (dental caries and periodontitis) (Aas et al., 2006; 2008).

Fluoride has anti-caries effect as it competes for the calcium ion in the enamel matrix after demineralization by the oral bacteria (Selwitz et al., 2007; Featherstone, 1999). The structure that is formed as a result of fluoride is more resistant to acid attack (Selwitz et al., 2007; Featherstone, 1999) and thus resists dental caries along with the inhibition of plaque bacteria (Featherstone, 1999).

Access to Oral Health Services

Dental insurance is one of the factors that determines not only access to dentists (Teusner et al., 2014; Brennan et al., 2013; Manski et al., 2004) but the receipt of regular dental visits (Anikeeva et al. 2013), especially among lower income groups (Locker et al. 2011). Persons with dental insurance have higher self-rated dental health than those without this insurance (Teuser et al. 2014). Lack of dental coverage leads to undetected diseases, like oral cancers, in middle-income adults in early stages. The RAND Health Insurance Experiment showed that eliminating or reducing co-pay improved the oral health of participants 35 years old and younger, and among those with poor oral health in terms of both DMFT and periodontitis (Bailit et al. 1985).

There are several factors that determine access to oral health services. Race, age, sex, SES, education, health insurance, dental workforce, and cost of services determined access to dentist and dental services for African Americans and Whites aged 18 years and above (Eisen et al. 2015). Among elderly aged 50 years and above, Manski et al. (2004) using the MEPS data, found that having teeth (OR=1.57), dental insurance (OR=2.53), higher income (referent level), higher education (OR=3.18), and being white (referent level) were the factors that were associated with a higher odds of dental visits. The use of dental services was more in the free dental care plans (66%) versus plans with deductibles (~50%) (Meyerhoefer et al. 2014). Mueller & Monheit (1988) used MEPS data for 1977 to compare the results with RAND Health Insurance Experiment and found that those who had some sort of dental coverage utilize dental services more than those who were uninsured (55-57% vs. 47% respectively). The mean number of dental visits was increased by 0.373 among persons with dental insurance (Munkin & Trivedi, 2009).

Choi (2011) found that Medicaid dental benefits increase the likelihood of dental visits to between 16.4—22% among people with low income level. In another study by Teusner et al. (2013), the authors found that dental insured adults were 57% more likely to make regular dental visits as compared to those who did not have dental insurance. Similar results were obtained by Brennan et al. (2013) where presence of dental insurance had a prevalence ratio of 1.48 of visiting a dentist in last 12 months.

Insurance determines access to health care services and lack of insurance not only isolates a person to access the health care services but it is associated with mortality (Wilper et al. 2009; Franks et al. 1993). Moreover, health insurance was also found to be associated with health and poverty level (Hoffman & Paradise, 2008).

Oral Health Disparities

Disparities in oral health exist both for dental caries and periodontitis among U.S. adults. Disparities in terms of race/ethnicity, education, and income determined the inequality in the receipt of oral health services: the burden of disease being the greatest among Black and Mexican Americans, those having less than a high school education, and low income (Borrell & Crawford, 2008). Disparities in access due to dental insurance have also been found to affect racial and ethnic minorities for preventive dental care utilization (Doty & Weech-Maldonado, 2003).

Disparities in oral health exist due to a number of factors. Patrick et al. (2006) defined it as a combination of biological, behavioral, social, economic, cultural, and political determinants. The biological determinants were the host defense mechanism that is genetically determined and could not be altered. The rest of the determinants could be altered. The behavioral determinants were the habits like the use of tobacco and alcoholic

products, frequency of the use of sugary products, oral hygiene practices, and attitude towards oral health and this behavior is changeable. Age, sex, race, and education status were found to be the predictors in influencing the behavioral pattern towards oral hygiene (Riley et al. 2006). The social determinants were education and counseling on the importance of good oral hygiene. The economic determinant was the dental insurance. Cultural determinants were the oral health beliefs and family perceptions on the importance of oral health. The political factors included the allocation of resources to oral health programs (like Medicaid). These determinants could be captured nicely under the umbrella of Andersen's model of health services utilization (Andersen 1995) and Donabedian's (1988) approach for quality assessment.

Andersen's Behavioral Model of Health Services Utilization

Andersen (1995) revised the behavioral model of health services utilization to aid the development of health policies for equitable access (fig.1). Donabedian's approach to quality assessment is based on three main approaches: structure, processes, and outcomes. According to Andersen's model, predisposing characteristics are composed of demographic (biological determinants in Patrick's model), social structure (social determinants in Patrick's model), and health beliefs (cultural determinants in Patrick's model) that determine the likelihood of the need for health services. Enabling resources (also the structure in Donabedian's approach and economic determinants in Patrick's model) are the means to get the health services like family income and dental insurance. Need (also the process in Donabedian's approach) is either the perceived need for dental care or diagnosed by the healthcare provider. The three population characteristics (see fig. 1) determine the health behavior of the patients (behavioral determinant in Patrick's

model) that determine the outcome. Outcome in both the Andersen's model and Donabedian's approach are the same that are related to patient satisfaction with healthcare provided, improvement in health related knowledge, and perceived health status. The political determinant shapes the overall healthcare system in the form of health policies that lead to outcomes.

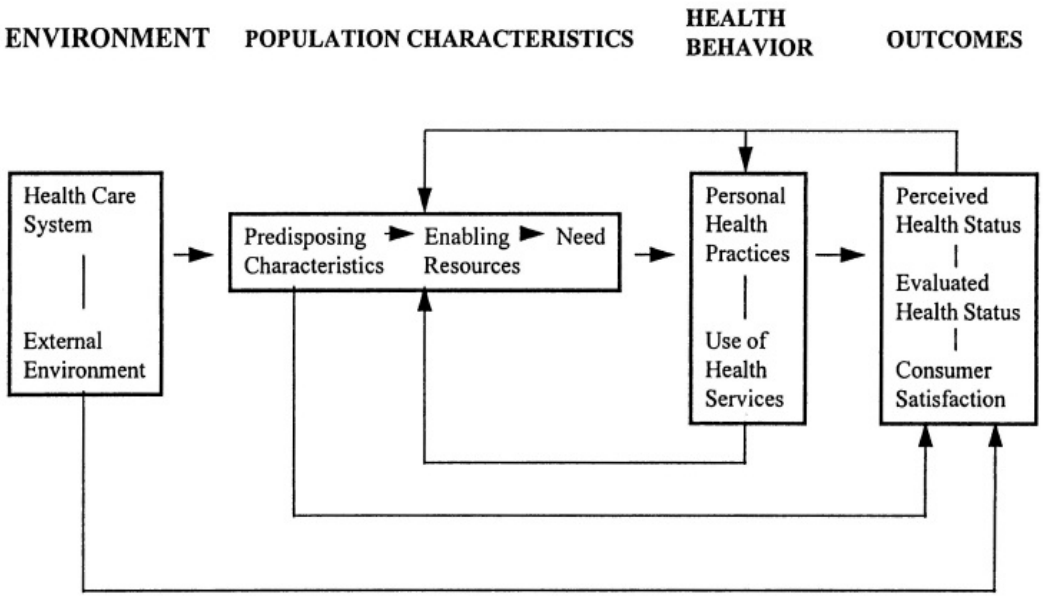

Fig. 2. 1 Andersen's Healthcare Model (Adapted from Andersen, 1995)

Disparities in the prevalence of dental caries had been observed among all age-groups, vulnerable racial ethnicities, people with lower education, lower income, and smokers. Non-Hispanic Blacks, smokers and older adults tend to lose more teeth and have poor dental quality of life (MMWR 2005). The frequency of visits to dentists, smoking status, and frequency of eating fresh fruits and vegetables were associated with socio-economic disparities in oral health (Sabbah et al., 2009). Eisen et al., (2015) conducted a study in a low median income community where Blacks and Whites live

together with no racial difference in median income. The study measured only the visits to dentists in the past two years. African Americans tended to have more dental visits in the past two years, had health insurance and better health and oral health as compared to their white counterparts. However, the study did not take into account dental insurance, whether better oral health was contributed to frequent visits to dentists, and if the visits were paid out of pocket or whether the health insurance provided oral health fringe benefits. Moreover, there was no prior information on the oral health status of the individuals in both the races (Blacks and Whites), or whether oral health beliefs were stronger in one race.

Periodontitis (especially severe periodontitis) tends to be more in minorities, having less than a high school education, and with limited access to dentists (Oliver et al. 1998). Increased weight also leads to the development or worsening of periodontitis, according to the meta-analysis conducted by Keller et al. (2015). Demographics and socioeconomic factors were found to be associated with periodontitis among population of Latin American countries (Oppermann et al. 2015). Numerous studies have been conducted to establish the link between periodontitis and various systemic diseases. The details of the association between periodontitis and systemic diseases could be followed below.

Underlying Mechanism Linking Oral Health and Systemic Diseases

In order to understand the relationship between oral health and systemic diseases, we must first understand the anatomy and physiology of the oral cavity.

Anatomy & Physiology of Mouth, Teeth, & Periodontium

Mouth is an open cavity that is exposed to external environment and harbors several bacteria and micro-organisms. It is lined with mucous membrane that appears red in color due to extensive blood supply in the oral cavity. The lining of the oral cavity is composed of squamous cells that is similar to the superficial layer of skin that has the property of desquamation. Desquamation is a process of shedding superficial layer of skin to replace with a new one that ensures optimal microbial load (Moore & Moore 1994).

Teeth have bulging smooth surfaces and irregular occlusal surfaces in the form of pits and fissures that are found on the pre-molars and molars. The outer surface of teeth is composed of enamel that is a mineralized structure and the only non-living surface in the body. Therefore, teeth are the only non-shedding surfaces (Li et al., 2000; Selwitz, Ismail, & Pitts, 2007; Marsh & Percival, 2006) and the formation of plaque on the surfaces of teeth make it a habitat for bacteria unless cleaned regularly. Strong masticatory forces that push the fibrous food against the bulging smooth surfaces of the teeth and the normal salivary flow, that maintains the pH, are the two natural mechanisms that help in keeping the microbial load to an optimal level on the surfaces of teeth. The vulnerable areas on teeth are the inter-dental areas and gingival crevices because food accumulation takes place there and are less likely to be cleaned by regular tooth brushing or by these natural mechanisms (Moore & Moore, 1994). The roots of the teeth are protected by periodontium that helps in anchoring and supporting the teeth in the jaw bones (Metivier, A., Bland, 2014).

Surrounding the neck of the teeth are the gingival crevices which are filled with nutritionally rich fluid, that provide a perfect medium to anaerobic oral flora to flourish. Therefore, the role of oral hygiene becomes very evident to keep the mouth and teeth healthy and this is the induced method of shedding off the oral flora from dental surfaces, oral mucosa, and tongue that help in keeping the microbial load to an optimal level.

Role of Saliva

Saliva performs many functions in the oral cavity due to a number of components that it contains. It acts a medium to provide nutrients to normal flora to keep occupying spaces in the oral cavity to prevent opportunistic microorganisms from taking over to avoid deleterious effects. Additionally, the IgG antibodies secreted in saliva also helps in protecting the oral cavity from external microorganisms. It also contains enzymes that help in carbohydrates digestion as soon as food bolus is put into mouth. Saliva also functions to maintain pH in the oral cavity by neutralizing the acids produced as a result of fermentation of sugars by the oral bacteria. But when the salivary flow becomes less either due to medications or illness or old age (Selwitz, Ismail, & Pitts, 2007), or the production of acids increases due to frequent intake of sugary foods and beverages, caries may follow.

Presence of teeth increase the number of bacteria in the oral cavity due to the presence of multiple surfaces on which the bacteria could adhere via plaque. With the loss of teeth, there are less bacteria but the use of dentures provide harbor to bacteria and oral fungus (candida albicans) and due to use of medications for chronic illnesses especially in old age, result in decreased salivary flow, the oral cavity becomes susceptible to oral infections in addition to low immunity in advanced age.

Dental Caries

Dental caries is a continuous and dynamic process (Carounanidy & Sathyanarayanan, 2010) of a change in equilibrium of decalcification and re-mineralization in the biofilm (plaque) that results in the localized destruction of tooth surface that is susceptible to the by-products (acids) of carbohydrate fermentation by the bacteria of the biofilm (Fejerskov & Kidd, 2008). Carbohydrate exposure before tooth eruption increases the chances of having dental caries later in life (Hujoel, 2009).

Dental caries is a multi-factorial disease that is affected by salivary flow, poor dietary habits including frequent consumption of sugars and sticky food, oral medications containing sugar, fluoride exposure either through community water fluoridation or through fluoridated toothpastes and dentifrices, and regular teeth cleaning by the individual (Selwitz, Ismail, & Pitts, 2007). With improved dental public health measures over the past half of the century (fluoridated water), more and more people are retaining teeth in old age (Dye et al. 2007) but at the cost of untreated dental decay (MMWR, 2005).

Literature on the relationship between oral health and mortality have focused mostly on cardiovascular disease. We will talk about a few studies under the heading of "Dental Caries and Associated Morbidity and Mortality" that established a weak link between dental caries and morbidity/mortality. Thus, this study tends to examine the relationship between the dental (coronal) caries and mortality.

Etiology of Dental Caries

Plaque is a major contributing factor in the initiation of dental caries. It is a thin layer of film that forms naturally on the surfaces of teeth immediately after teeth cleaning

and essentially protects the teeth from invasion of exogenous species of bacteria but it also adhere microbes that normally exist in the oral cavity to the tooth surface. This thin layer of plaque gets removed mechanically by tooth brushing and tooth flossing. When the plaque remains thin, saliva could penetrate the thin film to re-mineralize the tooth structure but once the plaque gets thick and mature, it becomes impossible for saliva to penetrate the plaque to re-mineralize the tooth surface (Usha,& R, S., 2009; Selwitz, Ismail, & Pitts, 2007). The composition of microbes that adhere to the tooth structure via plaque changes from aerobic gram-positive to non-aerobic gram-negative bacteria that are more acid-resistant and lead to demineralization of enamel surface. The regular and routine tooth brushing removes the superficial layer of plaque from the smooth surfaces of the teeth accessible by the tooth brush. For non-accessible areas in the teeth, dental flossing is recommended to remove plaque from areas that are not accessible with tooth brush. In addition to tooth brushing, tongue cleaning is necessary to manually scrap off food residues, bacteria, and degenerated superficial layer of tongue mucosa. This helps not only to keep the bacterial load to an optimal level but prevents halitosis (bad breath). However, patient education and proper techniques to clean teeth are highly important to keep an optimal level of oral hygiene. But in order to make the patients learn proper techniques, supervised training from dental hygienist is very helpful to patients in changing their habits (Bray, Catley, et al. 2013).

Flora of Oral Cavity

It was previously considered that only a few cultivable species of bacteria are known to cause dental caries. But the recent researches have shown that it is not only the cultivable but non-cultivable bacteria too that are present in dental caries. Aas et al.

(2005; 2008) conducted two studies to identify normal oral flora in healthy mouths in order to detect a shift in the balance of the bacteria that cause caries.

The oral flora of the humans has both cultivable and non-cultivable bacteria (Aas et. al 2005; Aas et. al 2008). Aas et al. conducted a research to study the normal and caries flora in the oral cavity of healthy and diseased mouth respectively. Depending upon Streptococcus mutans detectable presence in dental caries, there were other species of bacteria that were significantly higher in number than S. mutans, i.e to say that there is greater diversity of bacteria in carious permanent teeth. The researchers also found that the bacterial profile changes significantly on the surface of intact enamel in both healthy and caries-diseased mouth. The bacterial profile also changes from different stages of dental caries, whether the caries are limited to enamel or progressed to dentin.

Dental Caries and Associated Morbidity and Mortality

Johnston and Vieira (2014) examined the association of dental caries experience (DMFT and DMFS) with self-reported systemic diseases and found that dental caries is positively associated with hepatitis, high blood pressure, liver disease, asthma, diabetes, and stroke. A meta-analysis conducted by Hujoel (2009) showed that fermentable carbohydrates are responsible for both dental caries and periodontitis to cause obesity and diabetes, and dental diseases cannot be secluded from systemic diseases as localized diseases. Excess of consumption of sugar (up to 50 gm sucrose drink per day) leads to periodontal problems (Cheraskin et al. 1965).

Kim et al. (2013) studied the relationship between poor oral health and mortality. People with poor oral health had higher odds of dying with systemic diseases. However, the study focused on the number of missing teeth (15 or less), presence of root caries, and

periodontal problems but did not take into account the surface caries that are present on other teeth. Also, the age-group was not stratified to see different age-groups that could be at a higher risk of mortality due to the presence of caries not only on the root but also on the tooth surface. The root caries occur when periodontal problems exist, however, not every patient having periodontal problem can have root caries but having both root caries and periodontal problem is a very good indicator of poor oral hygiene. Also, deaths due to dental diseases could be due to diseases other than heart, stroke, diabetes, and cancer as outlined in the section (Systemic Diseases caused by dental caries & Periodontitis).

Periodontitis and Mortality

Periodontitis is a chronic inflammatory disease caused by infection of the supporting tissues around the teeth (Haffajee & Socransky, 1994). The common cause of both caries and periodontitis is the same, i.e. dental plaque.

Periodontitis leads to high levels of C-reactive protein (CRP), an inflammatory marker for cardiovascular diseases (Dye, Choudhary, et al. 2007; Wu, Trevisan, Genco, 2000), due to the presence of periodontitis-causing bacteria. A meta-analysis conducted by Beck & Offenbacher (2005), the authors found a strong evidence for cardio-vascular diseases, however, causality could not be determined. Using the NHANES I study, DeStefano et al (1993) found that both having poor oral hygiene (defined as the presence of debris on the surfaces of teeth) and periodontitis had an increased relative risk of 1.25 among both men and women aged 25-74 years and an increased relative risk (1.72) among only men aged 25-49 years old for development of cardiovascular heart problems and total mortality. The study also found that having no teeth had approximately the same relative risks for both cardio-vascular diseases and total mortality among both men and

women aged 25-74 years, however, in men aged 25-49 years the relative risk for total mortality was 2.60 for periodontitis. This study found no association of dental decay with cardiovascular diseases or death. A similar two fold increase in death rate was also found by Ajwani et al. (2003) in elderly population aged 76 years and above.

Etiology of Periodontitis

Normal oral flora is associated with healthy periodontium. However, dental plaque biofilm provides adhesion to pathogenic bacteria and when the dental plaque matures, it results in initiation of gingivitis to periodontitis (Kesic et al. 2008). However, like dental caries, other factors like host defenses also contribute to the extent of periodontal problems (Tatakis & Kumar, 2005). The microorganisms found in periodontitis had been found in other systemic diseases as found in one of the meta-analysis conducted by Nunn (2003). Several studies have been conducted on periodontitis that link the condition to various systemic conditions while dental caries have been neglected in most studies.

The detailed analyses for the study of pathological bacteria in dental caries and periodontitis carried out by Aas et al. (2008) and Nunn (2003) respectively show that the pathological bacteria both cultivable and non-cultivable are found in both the pathological conditions. But now we know through bacterial analyses that both dental caries and periodontitis share the same characteristics in the variety of both healthy and pathogenic microorganisms to a greater extent. There is also compelling evidence from the meta-analysis of Hujoel (2009) that fermentable carbohydrates consumption after tooth eruption is associated with higher chances of having periodontal problems.

Systemic Diseases caused by dental caries & Periodontitis

Epidemiology of Systemic Diseases due to Oro-Dental Reasons

Asthma

There is plethora of research that supports that association of caries with asthma (Anjomshoaa et al. 2009). Botelho et al. (2011) conducted a case-control study among asthmatic children to evaluate risk of having dental caries based on the levels of streptococcus mutans bacteria in saliva and DMFT index. They concluded that asthma is a risk factor for dental caries due to increased streptococcus mutans and dental bio-film. Also the B-2 medication used in asthma effects the salivary rate that in turn affects the level of streptococcus mutans and lactobacilli in the dental bio-film (Ryberg et al. 1987). However, Johnston and Vieira (2014) showed in their study that medications has no role to play with higher caries experience among asthmatics rather immune signaling genes have a role to play in the expression of asthma (Schmidt-Weber, 2006) that could explain higher caries experience among asthmatics (Johnston and Vieira, 2014). But the current recommended asthma prevention and treatment regimen is a combined use of both corticosteroids and a beta-2 blockers (Graham, & Eidb, 2014; Barnes, 2012). Corticosteroids are known to cause disruption of the oral flora that result in diseases like oral candidiasis (Battaglia et al., 2014), hoarseness, dry mouth, and stomatitis (Kajiwara et al., 2014) if mouth is not rinsed immediately after the use of dry-powder inhaler. One of the studies found women to have higher odds for not rinsing the mouth after dry-powder inhaler use and therefore at higher risk of developing the side effects of the steroid drug (Kajiwara et al., 2014).

Diabetes

Excess of carbohydrate intake and lack of exercise along with family history is a common risk factor for both dental caries and diabetes.

The literature for the link between diabetes and periodontitis is not clear but the occurrence of both the diseases simultaneously exacerbates bone loss in teeth leading to teeth mobility (Shay 2002). The meta-analysis by Shay (2002) also shows that improved oral hygiene leads to lesser occurrences of pneumonia and related symptoms among elderly in institutionalized settings and improved oral hygiene both by the patient and dental professionals may improve the general health and dental outcomes for the patients in general and elderly in special. Hintao et al. (2007) and Soni (2014) conducted a study on type II diabetic patients to find out that diabetes is a significant risk factor for root caries. Majority of the root caries lesions occur due to gingival recession while some of it occur due to periodontal pockets that does not involve gingival recession due to either crowned surfaces or coronal fillings (Locket et al. 1989).

"Diabetes is a marker of abnormal blood glucose metabolism" (Hujoel, 2009). The underlying factor for both dental diseases and diabetes is carbohydrates especially the fermentable carbohydrates (Hujoel, 2009) and has been associated with periodontal diseases (Tsai et al. 2002) and dental caries (Johnston and Vieira, 2014). Maintaining blood glucose through physical activity reduces the chances of periodontal problems in adults, thus providing less favorable environment to oral pathogens to grow (Merchant et al. 2003). Mummolo et al. (2014) also found a significant positive correlation between the number of teeth and diabetes.

Periodontitis may lead to manifest diabetes, trigger or act as a catalyst for diabetic complications, and pose risk for poor blood glucose levels (Borgnakke, 2013). Severe periodontitis has been shown to increase mortality risk for cardio-vascular diseases among diabetic Native Indian patients. The periodontal problems tend to be more among diabetic and edentulous Native Indians (Saremi et al. 2005).

Cardiovascular Diseases (including High BP)

A study conducted by DeStefano et al. (1993) using NHANES I showed that people who have gingivitis or periodontitis/no teeth had 23% and 50% respectively higher risk of cardiovascular mortality compared to those having no periodontitis. However, they failed to detect any effect of number of decayed permanent teeth on the risk of cardiovascular disease but they could not rule out the risk of having the CVD due to previous dental decay in the form of tooth loss. Adults between the ages of 25-49 years had a higher risk of cardio-vascular disease and total mortality due to both poor oral hygiene and periodontitis. Mattila et al. (1989) found an association between dental caries and acute myocardial infarction (heart attack). Both dental caries and cardiovascular diseases have a common underlying risk factor, sucrose (fermentable carbohydrate), that leads to high blood cholesterol and therefore, cardiovascular problems (Mattila et al. 1989). However, Joshipura et al. (2006) did not find any relationship between dental caries and cardiovascular diseases. It could be the effect of fluoride, either in community water or fluoride dentifrices/toothpaste, on teeth to have less number of dental caries (Hujoel 2009). But Joshipura et al. (2006) did find a positive relationship between dental pulp inflammation, using root canal treatment as a proxy measure, and cardiovascular diseases.

In another study by Tu et al. (2007), the researchers found that 9 or more missing teeth had 35% greater risk of mortality with cardiovascular diseases as compared to those with four or less than four teeth. However, the researchers did not describe the cause of tooth loss in their study, so we have no clue whether the tooth loss was due to dental caries, periodontitis, or trauma, but as the study was conducted among early adults, Yu et al. (2007) attributed tooth loss due to dental caries. Abnet et al. (2005) found an association between tooth loss due to periodontitis and cardiovascular diseases in a cohort study that was conducted among rural Chinese population. Watt et al. (2012), in addition to tooth loss, also found that edentulism (having no teeth at all) had a higher risk of all-cause and CVD mortality.

Root caries have been shown to be associated with cardiac arrhythmias in urban community-based population of age 80 years and above (Holm-Pedersen et al. 2005).

Shay (2002) conducted a meta-analysis on the infectious complications of dental and periodontal diseases in elderly and came to the conclusion that cardiovascular infections like endocarditis were caused by oral bacteria. In another meta-analysis by Loos (2005), the author came to the conclusion that bacteremia was caused by consistent presence of pathogenic periodontal bacteria that led to rise in C-reactive proteins, an inflammatory marker responsible for cardiovascular diseases. Bretz et al. (2005) found similar results of increased serum C-reactive proteins among elderly with periodontitis. If C-reactive protein is higher among patients with periodontal disease, then controlling for periodontal disease should lower the CRP. López et al. (2012) conducted a double blind randomized clinical trial among patients with metabolic syndrome, where they provided periodontal therapy along with antibiotics prescription to measure the level of CRP

among treated vs. controlled groups and found that periodontal therapy reduced the level of CRP after 9 months of therapy and so the risk for cardiovascular diseases. This finding was also confirmed by Teeuw et al. (2014) and Paraskevas et al. (2008) in their meta-analysis for the effect of periodontal therapy on atherosclerotic plaque biomarkers both in patients with cardiovascular diseases and diabetes. Even the low grade gingivitis induced systemic inflammatory markers that could lead to atherosclerotic plaque development resulting in various cardio-vascular diseases (Eberhard et al., 2013).

Cerebro-vascular diseases & Stroke

Johnston and Vieira (2014) found a positive relationship between dental caries and stroke. In another study conducted by You et al. (2009), the researchers found that tooth loss due to periodontal problems was associated with stroke and C-reactive protein. C-reactive protein is the bio-marker for systemic inflammation that is present during periodontitis (Pejcic et al., 2011; Ana et al., 2013) but You et al. (2009) did not find C-reactive proteins to be on the causal pathway between periodontitis and stroke. However, study by Abnet et al. (2005) found tooth loss due to periodontal reasons (suggested) to be associated with stroke. Also the general health of stroke patients remains poor with fewer visits to dentists' office (Dai et al. 2015). In a meta-analysis of cohort studies for periodontal disease and stroke, Lafon et al. (2014) found that both periodontitis and loss of teeth were strongly associated with the incidence of stroke. The number of teeth seemed to be associated with increased mortality with stroke as found by Watt et al. (2012) that edentate persons had higher risk of dying with stroke.

Okamoto (2012) reported two cases of cavernous sinus thrombosis (CST) one of which was caused by dental caries and the other by tooth extraction, though CST is rare but fatal if not diagnosed and treated at its earliest.

Taguchi et al. (2013) conducted an experimental study to find out if periodontitis causes changes in brain matter. The researchers found a positive relationship between periodontitis and changes in brain matter responsible for dementia. In another study conducted by Minn et al. (2013), the researchers found that tooth loss was associated with changes in the brain matter that lead to cognitive problems resulting in decreased cognition.

Batty et al. (2013) found similar results in diabetic 55-88 years old elderly having less than 22 teeth to have dementia and cognitive problems. Tooth loss could be due to either caries or periodontitis (Maxwell et al. 2014), however, Park et al. (2013) and Kamer et al. (2012) found that teeth loss due to periodontal problems were known to cause cognitive problems in elderly. Though nutritional problems were associated with dementia (Luchsinger & Mayeux, 2004) and tooth loss could lead to poor nutrition among the elderly but Batty et al. (2013) found no such association of dementia with nutritional deficiency. Similar results were found by Stewart et al. (2015) for statistically significant relationship between tooth loss due to periodontal reasons and dementia among women who participated in prospective population study of women. Zhu et al. (2014) also found that multiple tooth loss of 8 or more than 8 teeth was associated with cognitive impairment in patients who suffered from ischemic stroke. Being edentate had a high odds ratio for mild memory loss (Okamoto et al. 2014). Sparks Stein et al. (2012) in their case-control study found that serum antibodies produced as a result of

periodontitis could serve as a precursor for early mild cognitive impairment or Alzheimer's disease. Periodontal problems and number of teeth loss were reported to be associated with cognitive impairment in several other studies as well (Gil-Montoya et al. 2014; Nilsson et al. 2014;). In a meta-analysis conducted by Loos (2005), C-reactive protein produced as a result of periodontitis was reported by many to be associated with cerebrovascular diseases. Mummolo et al. (2014) found that reduced masticatory function due to teeth loss was associated with reduced cognition. A meta-analysis by Debelian et al. (1994) found that cerebral infarctions occur either due to thrombus or due to bacteria and fibrin aggregates whereas in some cases of brain abscesses, bacteria related to dental caries and/or periodontal problems have been found.

Epilepsy

Periodontitis exacerbated the severity of epileptic seizure among English patients in a case control study conducted by Costa et al. (2014). In a study conducted by Anjomshoaa et al. (2009), they found that caries is also associated with epilepsy. There was a hypothesis that it could be the effect of medicines that might lead to increased caries due to reduced salivary flow but a study conducted by Eeg-Olofsson et al. (1983) showed that there was no difference found in the prevalence of caries, the salivary flow rate, its buffering capacity, and the bacterial count between those taking anti-epileptic medication and the controls who did not take anti-epileptic medication. However, the intraoral effects (gingival overgrowth) faced by the patients using the anti-epileptic drugs were the side effects of the medication.

Hepatitis & Liver Diseases

Johnston and Vieira (2014) found an association with dental caries experience and liver disease and hepatitis. Hepatitis C patients were found to have higher number of missing and decayed teeth, however, filled teeth were found to be less, and had dry mouth due to less saliva production, in an Australian study conducted by Coates et al. (2000).

Diet & Obesity

Gocke et al. (2014) conducted a study from the longitudinal survey and found that there was a significant positive relationship between periodontitis and inflammatory markers among less abdominally obese participants. Prpić et al. (2012) developed a composite score for dental index based on dental caries, periodontitis, and tooth loss for their cross-sectional study and found an association between higher BMI and poor dental index irrespective of the participants' level of education and tooth-brushing habits.

Renal Function

Patients with end stage renal function suffered a variety of symptoms ranging from dry mouth and increased caries to calculus formation (Kaushik et al. 2013; Kho et al. 1999). Tadakamadla et al. (2014) found periodontal problems to get affected much more than dental caries in patients with chronic kidney diseases and the problem tended to get worsen with every increase in the stage of kidney diseases. Craig et al. (2007) found that mild to moderate periodontitis existed among patients with end stage renal disease and that biomarkers of systemic inflammation including CRP was higher among such patients. Strengthening Craig et al. (2007) findings, Gautam et al. (2014) and Borawski et al. (2007) found in their meta-analysis that periodontal disease existed in

chronic kidney conditions and patients undergoing hemodialysis, and it was severe in patients with both chronic kidney conditions and renal failure. In addition to oral manifestations of renal diseases and high biomarkers of systemic inflammation, tooth loss was also found to be associated with renal diseases (Mummolo et al. 2014; Ziebolz et al. 2012).

Cancer

Tooth loss is associated with upper gastro-intestinal tract cancer that includes cancers of esophagus, stomach, pancreas, liver, gall bladder, and biliary ducts (Ferretti, & Gafà, 2004). Abnet et al. (2005) conducted a longitudinal cohort study among rural Chinese population to measure the effects of tooth loss on upper gastro-intestinal tract (GI tract) and found that tooth loss is associated with upper GI tract cancers irrespective of smoking status and diet. It's an established fact that smoking and alcohol consumption increase the chances of getting cancer multi-folds. Smoking alone leads to dental caries (due to reduced salivation and decreased buffering capacity of saliva as a result of tobacco-smoking byproducts), tooth loss (due to local and systemic side effects of tobacco smoking that lead to alveolar bone loss), periodontal diseases, oral and lung cancers (Agnihotri et al. 2014).

Dental caries is a chronic infection and infection-induced inflammation has shown to be a cause of cancers (Allavena et al. 2008; Borrello et al. 2008; Rodriguez-Vita & Lawrence, 2010). Virtanen et al. (2014) showed in their study that dental caries induced inflammation (particularly due to missing second mandibular molar due to dental caries) led to different cancers of the body in patients with good periodontal health while on the opposite side, Tezal et al. (2013) found an inverse relationship between dental caries and

head and neck cancers. However, poor oral hygiene defined as not brushing teeth at least once a day was found to have greater chances of getting esophageal cancers (Dar et al. 2013).

Summary and research goals

As could be established from the above review that there are several studies that establish the link between periodontitis and systemic diseases, the relationship between dental caries and systemic diseases, though rare, but trending. The study by Kim et al. (2013) suggests that poor oral health defined as the less number of teeth, root caries presence, and poor periodontal health increases the risk of mortality. Similar study by Hämäläinen et al. (2003) suggested that the risk of death was reduced with the presence of more number of teeth or filled teeth in a Finnish community-dwelling elderly cohort. Mortality due to periodontitis is linked to various systemic diseases and the plethora of research on this topic above explains well the phenomenon. The aim of this study is to examine the relationship between dental caries and mortality, and periodontal problems and mortality in the light of access, racial/ethnic, and socioeconomic disparities.

CHAPTER 3

METHODOLOGY

Conceptual Framework

This study utilized Anderson Behavioral Model of Health Services (Andersen, 1995) and assumed that the removal of a barrier to access to dental care through dental insurance could lead to a reduction in mortality rate. The purpose of this study was to examine the mitigating effect of dental insurance on mortality risk among working age adults with dental caries and periodontitis.

Data Source

To answer the research questions, I used NHANES III dataset from 1988-1994. NHANES III is a complex, multi-stage sample of the non-institutionalized population of U.S. conducted by National Center for Health Statistics (NCHS) from 1988-1994. This dataset has a unique identification number (SEQN) that was linked to all other datasets in NHANES III. For the purpose of this study, all those who were interviewed and examined were included in the study as not everyone who was interviewed was examined. More details on NHANES III data collection and survey instruments could be found elsewhere (CDCe, 1996).

Study design and population

I used NHANES III dataset from 1988-1994, linked to mortality files associated with the corresponding years from the date of survey participation, Dec. 31st 1996 (NHANES 2006), till December 31st, 2011 using the NHANES sequence number.

Overall dataset was restricted to only working-age adults aged 20-64 years. Additionally, those participants for whom both the interview and examination had been completed were included in the study as the variables from both the interview and examination section were taken and we needed to have a complete information on both interviews and examinations to test the hypotheses.

For the first research question, edentulous in one or both the jaws were excluded from the study. Additionally, those who had a complete assessment of coronal caries, and restorations and tooth conditions were included in the study, the rest were excluded. Anyone having Medicaid, Medicare, and insurance from VA were also excluded from the study. The total sample size that came out of all the exclusion criteria was 8966, out of which 4311 were male and 4655 were female. The cut down of the total sample population is explained in the form of the diagram (see fig. 3.1).

For research question 2, after the application of working-age criteria 20-64 years age, and interview and examined both cut off criteria, the sample size was further restricted by excluding those that had medical conditions as this required permission from a physician to conduct detailed periodontal examination and therefore, not collected by NHANES III. Edentulous in one or both the jaws were excluded from the study. Furthermore, the sample was restricted to those who had a complete periodontal assessment of loss of attachment and probing depths. Also, those who had root caries were excluded from the study. The final sample size that came out of the exclusion criteria was 8746, males were 3990 and females were 4756. The cut down of the total sample population is explained in the form of the diagram (see fig. 3.2).

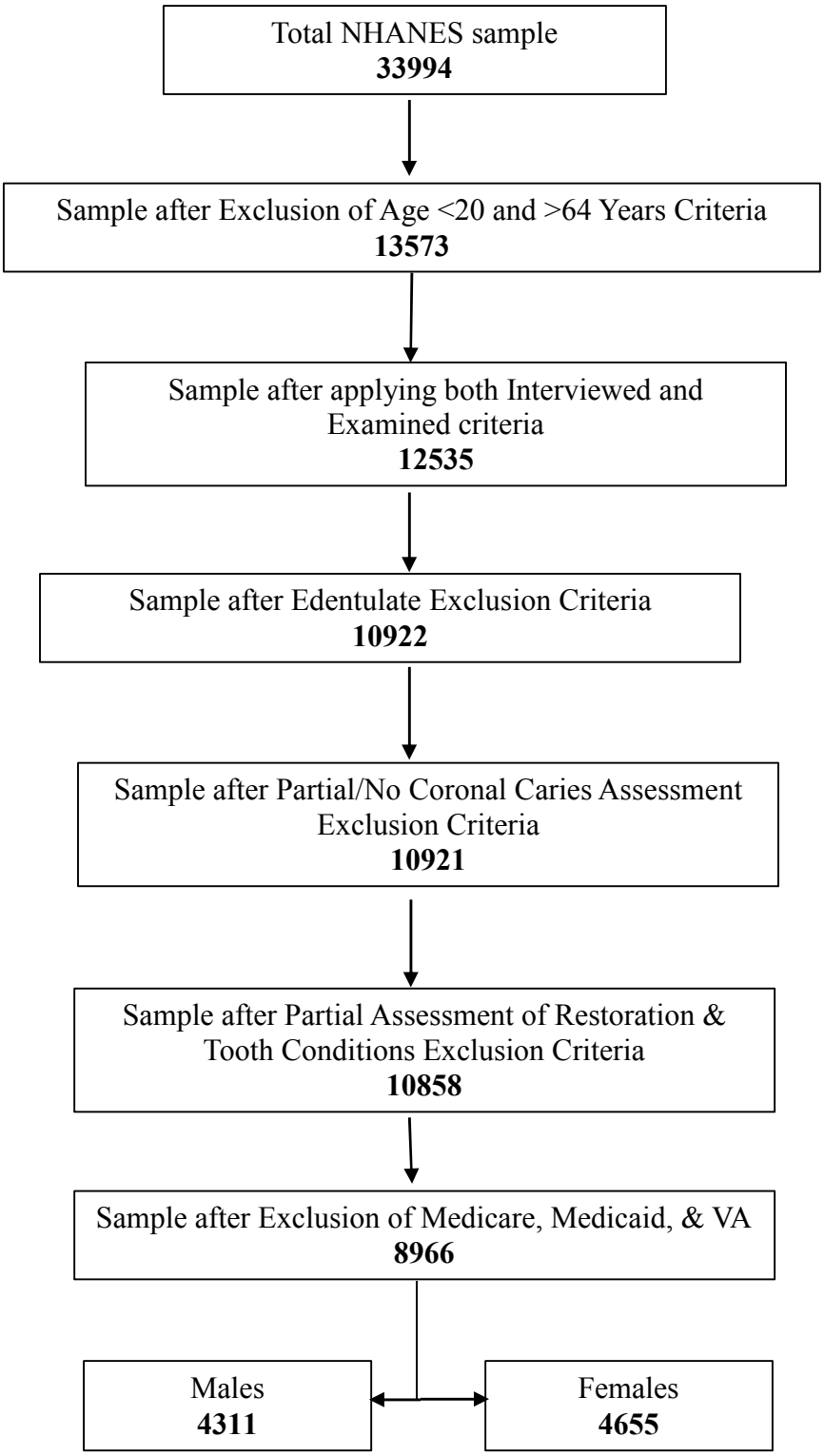

Fig. 3. 1 Schematic exclusion for Dental Caries

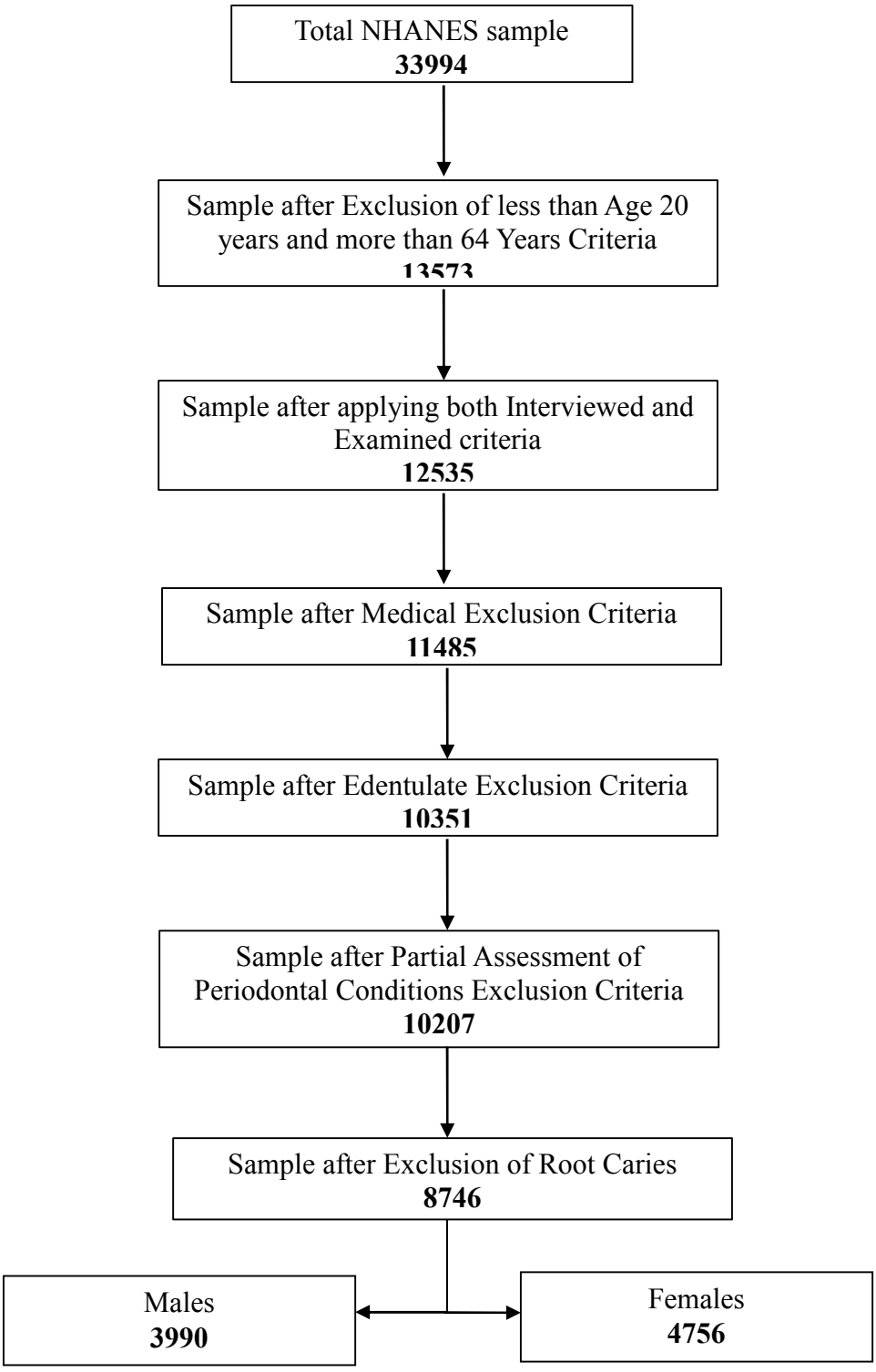

Fig. 3. 2 Schematic exclusion for periodontitis

Methodological Challenge of Using a Half-Mouth Protocol for Periodontitis

Though the prevalence of the disease is affected by the way it is measured and defined, CDC's definition of periodontitis takes into account only interproximal sites and ignores mid-buccal and mid-lingual sites, i.e. four out of six sites per tooth, thereby underestimating the true prevalence of periodontitis as demonstrated by Eke et al. (2010). Prior NHANES used visual examination for periodontitis (1960-1962) or used partial mouth periodontal examinations (PMPE) (1985-1986, 1988-1994, & 1999-2004) to record periodontitis, while full mouth periodontal examination (FMPE) protocol was only deployed in 2009-2010 NHANES (Eke et al., 2012).

According to Dye & Thornton-Evans (2007) on the history of the periodontal surveillance, it started as periodontal index (PI) that was based on a categorical scaled scoring system in all NHES surveys, NHANES I, and HHANES; all the teeth in PI were scored and a mean subject score was obtained. Because of no differentiation in measurement between gingivitis and periodontitis, and between different pockets depths, the index was more subjective than objective. To address this, Ramfjord in 1959 introduced periodontal disease index (PDI) to measure clinical attachment loss with the help of periodontal probe in six selected teeth to represent a full mouth. Though Ramfjord's PDI was never used in US National Surveys, however, the idea of partial mouth examination protocol using clinical attachment loss and probing depth was developed to be used in NHANES III, and NHANES 1999-2004 to reduce examination time and cost, and to develop different classification of periodontal diseases. In NHANES III, and NHANES 1999-2004, half-mouth protocol was used in which two out of six sites per tooth (MB & mid-Buccal) in two random quadrants (one maxillary and one

mandibular) of the mouth were taken. In 2001, a third site on tooth (DB) was added to improve the prevalence estimates for recording periodontitis. This measure of recording periodontitis is called partial mouth periodontal examination (PMPE).

Because periodontitis is not evenly distributed in the mouth and is site-specific, therefore, selected sites per tooth PMPE protocols underestimate prevalence (Kingman & Albandar, 2002; Kingman et al., 1988; Tran et al., 2013). Kingman et al. (2002) and Eke et al. (2010) recommended using a full mouth periodontal examination (FMPE) using all the six sites on the teeth in the whole mouth. However, due to financial reasons, national FMPE are rare (Kingman et al., 2002; Kingman et al., 2008). NHANES III used random half-mouth protocol to measure periodontitis, one random maxillary and one random mandibular quadrant (Eke et al., 2012). While it is established by various researchers that PMPE protocol underestimates the prevalence of periodontitis than the FMPE, however, the purpose of this study is not to estimate the prevalence of periodontitis but to analyze the effect of periodontitis on mortality using the definitions proposed by Eke et al. (2007). If underestimated periodontal prevalence is associated to deaths (if true), the association will be even greater for the true prevalence as this is the case of random misclassification (Eke et al. 2010; Kingman et al., 2008). However, Thomson & Williams (2002) found in their study that the crude odds ratio did not change significantly with changing prevalence with FMPE and RMPE (due to loss of information) collected data among young adults, implying that wider confidence intervals could be obtained with FMPE and less chances of having insignificant results. Peres et al. (2012) also found that the partial protocols (half mouth but measuring six sites per tooth) record sufficient information to measure the periodontal association with socio-demographics and

behavioral factors. Though the use of FMPE in NHANES (2009-2010) will be much useful to observe the correct effect of periodontitis on mortality, however, the current mortality file on CDC's record has fewer observed deaths to produce statistically viable results. For future purposes, it is recommended to use NHANES (2009-2010 and onwards) datasets to find out the true association of periodontal association with mortality.

Specificity & Sensitivity of Half/Partial Mouth Protocols

Several authors have proposed that all six sites per tooth are superior to selected sites per tooth in a random half mouth protocol (Vettore et al., 2007) and Dowsett et al. (2002) showed that with this half-mouth protocol, the mean CAL & PD for both FMPE and PMPE were the same, however, there was 7%-10% underestimate for PD $\geq$ 4mm or 6mm in age group of 18-24 years, and 2% to 13% overestimation for CAL $\geq$ 4mm or 6mm in age group of 65 years and above. The sensitivity of PMPE decreases with severe disease threshold but it always remained above 75%.

Specificity of all the PMPE protocol is 100% when compared to FMPE, however, the sensitivity varies with case definitions and measurement methods (Eke et al., 2010). Following CDC definitions proposed by Page & Eke (2007) and Eke et al. (2012), the sensitivity of NHANES III to detect true prevalence of severe, moderate, and total periodontitis is 40% when compared to NHANES 2009-2010 (Eke et al., 2010). The sensitivity of detecting moderate and severe periodontitis in a half-mouth exam with only one measured inter-proximal site (MB), according to CDC/AAP definition, is 47.5% and 23.7% respectively while for two inter-proximal sites (MB & DB), it is 63.3% and 39.0% respectively (Tran et al., 2014).

Eke et al. (2010) proposed that data from FMPE could be used to adjust the prevalence estimates of PMPE NHANES surveys through the use of inflation factors for misclassification bias (Kingman & Albandar, 2002; Susin et al., 2005; Albandar, 2011). The inflation factors that were computed are 2.7 for severe, and 2.4 for moderate and total periodontitis to adjust for underestimation of periodontitis (Eke et al., 2010). When Eke et al. (2012) applied PMPE protocol to NHANES (2009-2010) datasets, they found an inflation factor of 2.45 and 1.74 with NHANES III and NHANES (1999-2004) data respectively. Though the authors did propose that NHANES (2009-2010) is a superior dataset for etiologic research than the previous NHANES due to the use of FMPE protocol to capture true prevalence, however, the prevalence varies with the use of case definitions (Eke et al., 2012). CDC case definitions also underestimate true prevalence of periodontitis due to the way the periodontitis is defined as the inclusion of inter-proximal sites and not tanking in to account mid-buccal and mid-lingual sites (4 out of 6 sites per tooth) (Eke et al., 2012), therefore, even with FMPE, the true prevalence is underestimated under CDC periodontal definitions and therefore, the true association. However, for this study, CDC recommendations will be followed as the Federal Public Health Authority recommendations.

NHANES III utilized PMPE protocol to measure periodontitis. Susin et al. (2005) demonstrated that a FMPE showed a higher sensitivity followed by Mesiobuccal - Buccal – Distobuccal (MB-B-DB) PMPE protocol, and Mesiobuccal - Buccal (MB-B) PMPE protocol (Tran et al., 2013). NHANES 2001-2004 added DB site as an additional site for periodontal measurement, however, Susin et al. (2005) demonstrated that in three sites per tooth systems, sensitivities were better with DL (Disto-Lingual) site than with DB

(Kingman et al., 2008). The bias and relative bias for MB-B-DL PMPE were smaller for both half and full mouth versions (Kingman et al., 2008). However, characteristics of the population also affect the system of periodontal measurement (Susin et al. 2005).

Relative bias for the loss of attachment and probing pocket depth for NHANES III, 1999-2000, using MB-B sites, and NHANES 2001-2004 using MB-B-DB sites were very small (Kingman & Albandar, 2002). Peres et al. (2012) found in their study that for any partial mouth protocols, the sensitivity for periodontal pocket assessment is low, however, the prevalence of periodontal pockets is also low, implying that the total prevalence will not be much affected by its low prevalence. The sensitivity estimate for prevalence of attachment loss of ≥3mm for MB-B is 60% while that for MB-B-DB is 73% (Kingman & Albandar, 2002). The sensitivity for probing depth is good till ≥ 4mm for two sites per tooth PMPE, afterwards it deceases rapidly, 97% correct identification of cases with MB-B vs 99% with MB-B-DB PMPE ≥ 3mm and 73% correct identification with MB-B vs. 81% with MB-B-DB PMPE ≥ 4mm. The mean score of attachment loss for severe estimates of periodontal conditions (1.07) and relative bias (-8.55) for MB-B and MB-B-DB PMPE were found to be the same while the mean score for probing depth of MB-B was 1.93 vs. 2.09 for MB-B-DB and relative bias of -3.02 for MB-B vs. 5.03 for MB-B-DB. The sensitivity estimates decrease for PMPE ≥3mm. Based on these sensitivity estimates, inflation factors were calculated to obtain the true prevalence (Susin et al., 2005; Eke et al., 2010; Albandar, 2011). According to Tran et al. (2013), the NHANES III will be used to observe the association of periodontitis with mortality, as the use of 1999-2004 does not provide any added advantage except for

NHANES 2009-2010, for which the number of deaths are too less to be used for association analyses.

The mortality rate under NHANES 2009-2010 was very low before the application of any exclusion criteria, N= 134, to obtain statistically viable results. It will take about 6-7 years of mortality data collection to determine the true association of periodontitis with mortality in NHANES 2009-2010 (see table 3.1).

Table 3. 1 Number of Mortality in NHANES 2009-2010

Final Mortality Status				
MORTSTAT	**Frequency**	**Percent**	**Cumulative Frequency**	**Cumulative Percent**
Assumed alive	6376	97.94	6376	97.94
Assumed deceased	134	2.06	6510	100
Frequency Missing = 4027				

In summary, all sites per tooth half mouth periodontal examinations are better than selected sites half mouth (Chu & Ouyang, 2015), and the gold standard is all sites full mouth periodontal examination. However, the definition criteria also affects the prevalence rate. In the light of this, current CDC criteria (4/6 sites per tooth) to measure periodontitis underestimate prevalence of periodontitis by 8.8% (absolute bias) with an overall sensitivity of 84.28% when compared to all six sites per tooth, though a sensitivity of higher validity. NHANES III PMPE protocols have a sensitivity of low validity that will underestimate the risk (Albandar, 2011), however, the direction of association will be correct and reliable. There is a need to measure the true prevalence of periodontitis in U.S. population by reaching a consensus on the defining periodontitis

(Albandar, 2011). The older data showed underestimated relationship due to partial measurement, the new data will show a much more strong relationship ("Periodontal disease incidence," n.d.). The previous researches are not nullified for the direction of association as this was the case of random misclassification where the association value is underestimated and is directed towards the null, hence, the new data will lead to a much higher value of association, also known as the true association. It is known for certain that periodontal problems do lead to various systemic morbidities and the problem of periodontitis is much serious than was considered, as it has numerous systemic manifestations ("Gum Disease Found to be Significant Public Health Concern," n.d.).

Use of NHANES and other databases for Periodontitis and its association with Systemic Diseases

Several authors have published reports on the association of periodontal disease and systemic health. Taylor et al. (2000) using the NHANES III showed that periodontitis is an etiologic factor for type 2 diabetes and aspiration pneumonia. A recent study published by Lula et al. (2014) using NHANES III data showed that high frequency consumption of added sugars was associated with periodontal disease that could lead to other systemic diseases, using bleeding on probing and pocket depth of ≥ 3mm as a criteria for assigning periodontitis. Several other studies utilized NHANES III to observe the association of periodontitis with other systemic diseases used either probing depths ≥4mm or clinical attachment loss of ≥4mm or both (Chapple et al., 2007; Tomar & Asma, 2000; Morita et al., 2009; Wood et al., 2003; Arbes et al., 1999; Albandar et al., 1999; Xu & Lu, 2011; Saremi et al., 2005). The positive association of periodontitis with

systemic diseases has also been established by other studies that used datasets other than NHANES (Noble et al., 2014; Wowern et al., 1994; Elter et al., 2004).

Measurement

Dependent Variable: Mortality

All-cause mortality was taken into account for analyses as this was the only piece of information that was available in public-use datasets. More information on all-cause mortality could be found elsewhere (CDCd, 2013). In the public use data file, the exact date of mortality was not known, however, the month of death was available and the person month of follow from the date of examination (PERMTH_EXM) had been created by NCHS.

The mortality variable (MORTSTAT) was a dichotomous measure in this study; assumed deceased or assumed alive. Those who were ineligible for mortality follow up was coded as missing.

Independent variables

There were two independent variables that were used for two different research questions, for the first research question, it was untreated dental caries and for the second research question, it was the total periodontitis.

Measurement of Untreated Decayed Teeth

This independent variable is for the first research question. Untreated decayed teeth had three levels: no untreated decayed teeth, 1 untreated decayed teeth, and 2-23 decayed teeth among males and 2-20 untreated decayed teeth among females.

Measurement of Periodontitis

Page & Eke (2007) have described in detail the criteria on how to measure moderate and severe periodontitis, while Eke, Page, and Wei (2012) have described the method of measuring the mild and total periodontitis, using the clinical attachment loss and pocket depth of the gingiva for all the 28 teeth. Third molars were excluded from measurement as not everyone has erupted third molars (wisdom teeth), some have congenitally missing, and some have surgically extracted. This variable had two levels: no/mild periodontitis and moderate/severe periodontitis.

The following four levels of periodontitis was created initially and later mild and no periodontitis were merged together to create one level as 'no periodontitis'. Moderate and severe periodontitis were merged to as 'have periodontitis'.

- Mild periodontitis: Two or more than two interproximal sites with clinical attachment loss of ≥ 3 mm and two or more interproximal sites with pocket depth of ≥ 4 mm (not on same tooth), or one site with pocket depth of ≥ 5 mm.
- Moderate periodontitis: Two or more interproximal sites with clinical attachment loss of ≥ 4 mm, not on the same tooth, or two or more interproximal sites with pocket depth of ≥ 5 mm, not on the same tooth.
- Severe periodontitis: Two or more interproximal sites with clinical attachment loss of ≥ 6 mm, not on the same tooth, and one interproximal sites with pocket depth of ≥ 5 mm, not on the same tooth

Anderson's Model of Healthcare Utilization

Enabling resources (also the structure in Donabedian's approach) are the means to get the health services like dental insurance, which acts as a moderator in this study. Other proxy measure of enabling resources are visits to dentists and dental hygienists, and poverty income ratio.

Dental Insurance – Moderating Variable: Two different versions of dental insurance questions were asked in NHANES III in six years of data collection. In the first version, it was asked that "if the person is covered by health insurance that pays any part of dental care?" while in the second, third, and fourth version, there was a parent question that asked "During the last month was [sample person] covered by one or more health insurance plans obtained privately or through an employer or union?" for which there was a sub-part of the same question that asked, "Did any of these plans cover any part of dental care?"

Due to the difference in the pattern of the two questions, one asking if any of the health insurance plan covers dental care and the other if any of the dental care is through a private source, employer, or union, there was a need to make both the questions same. As the question regarding the source of dental care through a private source could not be deconstructed, therefore, the dental care question from version 1 was deconstructed to reflect the source of dental care through the following way.

The question "During the last month was [sample person] covered by one or more health insurance plans obtained privately or through an employer or union?" (HFB11) was asked in all the four versions of the questionnaire throughout NHANES III (see table 3.2).

Table 3. 2 Private Health Insurance asked in all four versions of survey questionnaire

Covered by other health insurance last month)	Version of household family questionnaire				
	1	2	3	4	Total
Yes (Freq)	3447	529	1366	2469	7811
%age	44.13	6.77	17.49	31.61	
No (Freq)	338	47	123	291	799
%age	42.3	5.88	15.39	36.42	
Total (Freq)	3785	576	1489	2760	8610
%age	43.96	6.69	17.29	32.06	100
Frequency Missing = 3670					

The question in version 1 that asked about "any health insurance that covers dental care" (HFB17) was matched with the question "if the health insurance plans were obtained privately or through an employer or union" to create a same variable for private dental care as that asked in version 2, 3, and 4 (if the health insurance from private source, employer, or union covers dental care, see table 3.3).

Any other health insurance that covers dental care was considered as no dental insurance. Medicaid is state-based and the coverage for dental care among adults is very limited and in most cases, it is equivalent to non-existent. Therefore, any dental benefit provided by Medicaid was translated into as having no dental coverage. The following table will make it easy to understand the creation of private dental source of care from version 1 (see table 3.4).

Table 3. 3 Insurance that pays any dental asked in all four versions of survey questionnaire

Insurance that pays any dental (Phase1)	Version of household family questionnaire				
	1	2	3	4	Total
Yes (Freq)	2083	0	0	0	2083
%age	41.17	0	0	0	41.17
No (Freq)	2976	0	0	0	2976
%age	58.83	0	0	0	58.83
Total (Freq)	5059	0	0	0	5059
%ge	100	0	0	0	100
Frequency Missing = 7221					

Dental insurance variable had three levels, indicating whether the person had private dental coverage, only health insurance from a private source, and uninsured.

Dental Insurance: It is defined as those who have a health insurance from private source, employer, or union that covers dental care. This will be the variables (HFB11C & Pvt. Dental Insurance variable created above from version 1).

Only Health Insurance: Anyone who had any type of health insurance excluding those who had health insurance with dental insurance to avoid redundancy (HFB13 minus Dental Insurance).

Uninsured: Any person who had not any sort of health coverage (HFB13).

Dental Visits: Visits to a dentist or dental hygienist (HAQ4) was captured into three categories;

Table 3. 4 Dental Insurance that is covered by Private health insurance plans

Insurance that pays any dental (phase 1)	Covered by Pvt health insurance last month		
	Yes	No	Total
Yes (Freq)	1895	19	1914
%age	99.01	0.99	
No (Freq)	1464	312	1776
%age	82.43	17.57	
Total (Freq)	3359	331	3690
%age	91.03	8.97	100
Frequency Missing = 8590			

- Those who never visited,
- Those who visited regularly at least once a year or every two years, and
- Who visited episodically as less often than every two years, whenever needed, and other or doesn't go any more (blank but applicable and don't know will be included in this category).

Family to Poverty Ratio: It is the ratio of the family income to poverty threshold. The value in this dataset ranges from 0 to <12. This variable had four categories; any value below 1 was considered to be living under federal poverty level, value of 1 and less than 2 meant that the family was living between 100% and 200% federal poverty level, value of 2 and above meant that the family was living 200% above the federal poverty level. Those who did not disclose the income were coded as missing to retain the observations in multivariate analyses.

Predisposing characteristics: are composed of demographic, social structure, and health beliefs that determine the likelihood of the need for health services. The following variables shape the demographic, social structure, and health beliefs of the individuals.

- Age: As discussed earlier, the age was restricted to 20-64 years. It was used as a continuous variable.
- Race/Ethnicity: Race/Ethnicity was categorized into four: Whites, Blacks, Mexican-Americans, and Others.
- Gender: Gender was classified into two groups as male and female.
- Marital status: Marital status had three categories: Married, Widowed/Separated/Divorced, and Single.

Rurality: This category had two levels based on USDA classification codes. Rurality acts as a proxy variable for dental health physician shortage area.

- Urban: Central/Fringe counties of metro areas of 1 million population or more.
- Rural: All other areas

Census Region: This was a categorical variable with 4 categories based on the census region. For this survey, not all the states were included in the selected sample, therefore, regional estimates may not be representative for a given region (NHANES III Adult Questionnaire).

- Northeast
- Midwest
- South
- West

Language of Interview: This category had two levels based on the language used during the interview. Language could be a barrier both in the purchase of insurance and in the receipt of dental and medical services. This was a proxy variable for the ability of the person to communicate to the outside world.

- English
- Spanish/Other.

Education was categorized into three:

  - Less than high school,
  - High school, and
  - College degree or above.

Family size had three categories as: a family of 1-2 individuals, a family of 3-4 individuals, and a family of 5 or more individuals.

Need (also the process in Donabedian's approach) is either the perceived need for dental care or diagnosed by the healthcare provider. These were the independent variables in this study.

- Charlson's Comorbidity Index: Charlson's co-morbidity index calculates the risk of dying within ten years due to co-morbid conditions. For this study, I intended to use this index to control for the co-morbid conditions. The following numeric weights were applied for each of the conditions based on the guidelines provided by Charlson et al., (1987)
  - 1 point for each of the conditions: Diabetes, asthma, cardio-vascular diseases (congestive heart failure, coronary heart disease, heart attack), stroke.
  - 6 points for cancer diseases
- Self-Described Health Status (HAB1): Self-rated health status is a good indicator of pre-mature mortality (Probst et al., 2011) and was used as a dichotomous variable in this study as follows:

- Excellent/Very Good/Good
- Fair/poor

- Self-Described Dental Health Status (HAQ1): Self-rated dental health status was used as a dichotomous variable in this study as follows:
  - Excellent/Very Good/Good
  - Fair/poor

Behavioral Factors

The following variables were the behavioral factors in this study based on the literature review.

- Alcohol use: This variable had three categories:
  - Current Drinker was defined as the person who had had at least 12 alcoholic beverages in the past one year at the time of survey.
  - Former Drinker was defined as the person who didn't have had any alcoholic beverage during the past one year but had at least 12 drinks in lifetime at the time of survey.
  - Never Drinker was defined as the person who never had any alcoholic beverage in lifetime at the time of survey.
- Tobacco use: Tobacco use had three categories as defined below:
  - Current Tobacco User: a person who currently used any form of tobacco product (cigarette, pipe, cigar, snuff, chewing tobacco) at the time of survey.
  - Former Tobacco User: a person who smoked at least 100 cigarettes in life but did not smoke cigarettes at the time of survey, and did not smoke 20

cigars or 20 pipes of tobacco at the time of survey, and did not use tobacco in any other form (snuff and chewing tobacco) at the time of survey but have used all these products in lifetime at the time of survey.

  - Never Tobacco User: a person who never smoked 100 cigarettes in life, and never smoked 20 cigars or 20 pipes of tobacco at the time of survey, and never used tobacco in any other form (snuff and chewing tobacco) at the time of survey at the time of survey.

- BMI: Body Mass Index (BMI) had four categories. Higher BMI is a risk factor for diabetes.
  - Underweight: a person who had a BMI of less than 18.5 kg/m^2 at the time of survey.
  - Normal Weight: a person who fell in the BMI range of 18.5 kg/m^2 to less than 25.00 kg/m^2 at the time of survey.
  - Overweight: a person who fell in the BMI range of 25.00 kg/m^2 to less than 30.00 kg/m^2 at the time of survey.
  - Obese: a person who fell in the BMI range of 30.00 kg/m^2 or more at the time of survey.
- Physical activity/exercise: It was a dichotomous category.
  - Yes: A person who performed any of the physical activity (walked or biked in the past 30 days, did any task around home/yard for at least 10 minutes during the past 30 days, did any moderate or vigorous activity over the past 30 days for at least 10 minutes, did any muscle strengthening over the past 30 days) at the time of survey.

- No: A person who did not perform any of the physical activity (walked or biked in the past 30 days, did any task around home/yard for at least 10 minutes during the past 30 days, did any moderate or vigorous activity over the past 30 days for at least 10 minutes, did any muscle strengthening over the past 30 days) at the time of survey.

Statistical Analyses:

All statistical analyses were conducted in SAS v9.4 using proc survey to adjust for the complex statistical modeling using weights, strata, and cluster variable to reflect the national population of U.S.

Descriptive statistics was obtained for all the variables mentioned in the above table followed by bivariate statistics with chi-square values of the above variables against the dependent variable, mortstat, which is the mortality status of the surveyed individual. Bivariate statistics were also obtained with chi-square values between Dental Insurance and Pre-Disposing, Enabling, and Confounding Variables.

Propensity Score Analysis:

The idea behind the propensity score is to replace several confounders in an observational study with one covariate, called propensity score (Rubin, 1997). In this study, the propensity score measured the likelihood of a person to have health insurance only or be uninsured as compared to the referent condition that the person had private dental insurance with health insurance. This score was computed on an individual level without survey weights utilizing individual characteristics laid out in the multinomial logistic regression formula. The two probabilistic scores (one for health insurance only

and the other for uninsured) computed by this technique reflected the likelihood of being in one of the three insurance statuses.

The score computed by this technique was used as a covariate (Rubin, 1997) in multivariate regression analysis to control for the differential probability of having dental insurance, applying survey weights and considering for other complex sampling strategy of the survey.

We see from the table in appendix I that private dental insurance with health insurance was disproportionately distributed among various demographics. For example, among age-groups we see that younger age-group (20-45 years) had the highest percentage of private dental insurance with health insurance as compared to 46-64 years (22.61%) and 65 years and above (5.72%). The difference was also particularly noticeable among race, marital status, and language of interview with whites having private dental insurance with health insurance as 79.93%, married having 73.68%, and English speakers as 97.89%. College degree and above with 57.45%, smaller family size of 1-4 members (43.07% for 1-2 members and 42.58% for 3-4 members), people residing in urban areas (55.85% vs 44.15% for rural), and people living in the south census region with 32.20% having private dental insurance with health insurance.

As I planned to see the effect of having dental insurance on mortality, and dental insurance was not uniformly distributed among different demographics, I obtained propensity scores in order to compensate for the differential propensity of having dental insurance as proposed by Rosenbaum & Rubin (1983). Based on gender, separate propensity scores were obtained to compensate for gender based death rates in the later analyses.

Model for propensity scoring:

Having dental insurance (Y=1) = constant + beta (age + race + education + marital status + total number of household + annual household income + language of interview)

The continuous probabilistic score that was created through this probabilistic logistic regression analysis, for those having dental insurance was converted into a categorical variable in the form of quartiles to control for the differences in the probability of having dental insurance against those not having dental insurance. The four level categorical probabilistic score that was created, was used as a variable in the cox proportional hazard model.

Survival / Mortality Analyses:

In order to see the association between mortality and different demographic factors and co-morbidities, multivariate proportional hazard analyses was run to obtain the hazard ratios. The analyses were separated based on gender as the mortality varies between the two genders.

For the all the research questions, the following proportional hazard (PH) statistical model was used to obtain the hazard rate due to dental caries and periodontal diseases.

$$h(t) = \lim_{\Delta t \to 0} \frac{P(t \leq T < t + \Delta t | T \geq t)}{\Delta t}.$$

The proportional hazard model was adjusted for the propensity scores for dental insurance along with other enabling, need, and pre-disposing variables.

The survival models that were run for the individual research questions are as follow:

RQ1: To assess the mitigating effect of private dental coverage with private health insurance on the risk of all-cause mortality among males and females with untreated dental decay.

Untreated dental caries was measured through the criteria laid out in the independent variable section. I obtained a 2x2 table to see that there are sufficient number of observations in each cell to produce statistically viable results (see table 3.5).

RQ2: To determine the difference in survival among people with private dental insurance having periodontal diseases controlling for co-morbidities.

Using the no periodontitis and moderate/severe periodontitis, hazard ratios were calculated to see the effect of every level of periodontitis on mortality. I obtained a 2x2 table to see that there are sufficient number of observations in each cell to produce statistically viable results (see table 3.6).

Limitations

There were some limitations related to this study. First, it is a cross-sectional study and does not reveal causality.

Secondly, being ineligible to obtain funding to access the restricted dataset for specific causes of mortality, all-cause mortality has been taken in to account for this study.

Table 3. 5 Total mortality against insurance categories in working-age group with untreated decayed teeth

Final Mortality Status	Dental Insurance			
	Uninsured	Pvt Dental Ins with Health Insurance	Only Health Ins	Total
Assumed alive (Frequency)	2162	4041	3302	9505
Row percent	22.75	42.51	34.74	74.79
Assumed deceased (Frequency)	259	769	2176	3204
Row percent	8.08	24	67.92	25.21
Total (Frequency)	2421	4810	5478	12709
Row percent	19.05	37.85	43.1	100
Frequency Missing = 629				

Table 3. 6 Total mortality against insurance categories in working-age group with periodontitis

Final Mortality Status	Dental Insurance			
	Uninsured	Pvt. Dental Ins with Health Insurance	Only Health Ins	Total
Assumed alive (Frequency)	2075	3811	3128	9014
Row percent	23.02	42.28	34.7	74.79
Assumed deceased (Frequency)	245	669	1858	2772
Row percent	8.84	24.13	67.03	25.21
Total (Frequency)	2320	4480	4986	11786
Row percent	19.68	38.01	42.3	100
Frequency Missing = 588				

CHAPTER 4

DOES DENTAL COVERAGE INFLUENCE THE RELATIONSHIP BETWEEN UNTREATED DENTAL DECAY AND MORTALITY AMONG WORKING AGE ADULTS? EVIDENCE FROM NHANES III[1]

[1]Sadiq, N., Probst, J.C., Martin, A.B., Khan, M., Merchant, A.T. To be submitted to the Journal of Dental Research.

Abstract

Purpose: The purpose of this study was to assess the mitigating effect of private dental coverage on the risk of mortality among working age adults with untreated decayed teeth. **Methods:** NHANES III dataset was linked to mortality dataset. Analysis was limited to those who fell between ages 20-64 years. Variables based on Andersen's model of healthcare utilization were used in incremental technique to observe the mitigating effect of dental insurance. Propensity score for dental coverage was calculated using the multinomial logistic regression and the corresponding score was used to adjust for the differential distribution of dental insurance in the population. All analyses were conducted using SAS v9.4 and weighted to represent the national population separated by gender. **Results:** Those who had private dental coverage had the lowest death rate among both male and female. Also, the death rate was less among those who had no untreated decayed teeth as compared to those who had 2 or more untreated decayed teeth in unadjusted mortality analysis. However, in multivariate adjusted cox proportional model, no effect of private dental coverage was observed on mortality risk in both males and females of working-age. **Conclusions:** Private dental coverage is not need to prevent the risk of mortality, though it may have other virtues. The depth of coverage, cost-sharing, and financial incentives could be some of the reasons for insignificant risk of mortality among both males and females of working age group.

Introduction

Dental caries is a chronic disease that occurs due to localized destruction of susceptible dental hard tissue as a result of the production of acid by-product from bacterial fermentation of dietary carbohydrates (CDCa, 2014). Dental caries start with

plaque formation that harbors several bacteria that lead to demineralization of tooth structure. Dental caries, if left untreated, could lead to inflammation of pulp or peri-apical abscess formation that could result in bacteremia or circulation of bacterial toxins in the blood leading to non-oral diseases (Li et al., 2000).

Oral health had been regarded a silent epidemic that has effects on both mouth and the whole body (Benjamin, 2010). There is a plethora of evidence of the relationship between poor oral health and negative outcomes including death (Navazesh & Mulligan, 1995; Jansson et al., 2002; Kim et al., 2013). Johnston and Vieira (2014) found a positive association between the prevalence of dental caries and self-reported systemic diseases like diabetes, liver diseases, stroke, blood pressure, asthma, and hepatitis. According to National Center for Health Statistics (2014), the prevalence of dental caries among adults aged 20-44 years was 27.4% and for 45-64 years, it was 19.9% in 2011-2012 NHANES, untreated decay being predominant among those living below 100% of FPL (Borrell & Crawford, 2008; NCHS, 2014) and minorities (NCHS, 2014). Therefore, minorities and people with low income with dental caries could be at a higher risk for mortality.

Dental caries is a preventable disease (Balakrishnan et al., 2000) and upon occurrence could be intercepted in its early stage by accessing a dentist. Access to dental health services is determined by availability of dental coverage (Teusner et al., 2014; Brennan et al., 2013; Bloom & Cohen, 2010; Manski et al., 2004; Bhatti et al., 2007). NCHS (2014) reported that most of the people living under 100% of FPL had the highest rate of dental caries and the lower income groups are the one who had a restricted access to the healthcare services (Locker et al. 2011) that affect their regular dental visits (Anikeeva et al. 2013).

In 2008, the prevalence of dental coverage was about 73% for adults below the age of 65 years (Bloom & Cohen, 2010). Dental coverage is mostly provided as an employee fringe benefit (Manning et al., 1985). Dental benefits for Medicaid are state dependent for adults aged 21 years and above, if it provides dental benefits, it is very limited and there is less financial incentive for dentists to participate in Medicaid dental program (Bloom & Cohen, 2010; Singhal et al., 2015).

Female gender, being White, people with higher education, higher income, having private medical insurance with or without dental coverage were more likely to have dental visits (Manski and Cooper, 2007). In view of Birch & Anderson (2005), the cost of dental services is either out of pocket or through private dental insurance in the absence of universal public funded program. While cost-sharing determines the uptake of dental services impacting dental visits (Millar & Locker, 1999), it was also cited a great barrier among Canadian adults for not visiting a dentist as compared to visiting a physician due to the dependency on cost-sharing to access to dental services (Birch and Anderson 2005). Therefore, foregoing dental care due to cost was found to be one of the factors that led to poor oral health (Thompson et al., 2014; Stafford et al., 2010). People with private dental coverage are more likely to visit a dentist, have regular dental check-ups (Carter & Stewart, 2003), higher dental expenditures (Christian & Chattopadhyay, 2014; Manski et al. 2002; Manski and Cooper, 2007), and higher number of dental visits than those who do not have private dental coverage (Manski et al. 2002; Manski and Cooper, 2007). In dental insurance, it's not the adverse selection that determines the utilization of dental services but the reduction in the price of the received dental care at the time of care reception (Bhatti et al., 2007).

Based on the literature that dental caries lead to various systemic diseases that could lead to death, the purpose of this study was to ascertain if private dental insurance could mitigate the risk of mortality among working age-group of U.S. adults with untreated dental caries.

Methodology

This study used the public-use NHANES III dataset. NHANES III is a complex, multi-stage sample of the non-institutionalized population of U.S. conducted by National Center for Health Statistics (NCHS) from 1988-1994. Further information on NHANES III data collection and survey instruments could be found elsewhere (CDCb, 1996). This dataset has a unique identifier, called respondent sequence number (SEQN), in all the datasets for linkage purposes, therefore, the publicly available household and examination data was linked to publicly available mortality dataset. NCHS regularly updates the mortality dataset for the individuals who participated in this study with the death certificates found in the National Death Index. It was most recently updated through December 31st, 2011. As the time span for mortality follow up of NAHNES III was the longest among other NHANES datasets, and because of this time length, the mortality rate was the highest, this allowed for a better precision of mortality estimates.

Inclusion / Exclusion Criteria

Only those persons who were both interviewed and examined both in the mobile examination center and/or their homes were included in the analyses. More details on examination procedures could be found elsewhere (CDCc). Furthermore, analysis was restricted to only ages between 20-64 years to include only working age adults. Persons who were edentulous in one or both the jaws, or had partial or incomplete assessment of

coronal caries, restorations, and tooth conditions were excluded from the analysis in order to correctly analyze the associations among persons who were completely or partially dentate in both the jaws. Those on Medicaid (n= 951, 9.27% of the study population) were excluded from the study due to the fact that dental benefits provided by Medicaid are state-dependent and we did not have information available in public-use dataset about respondent's state of residence in order to identify state by state dental benefits for adults under the umbrella of Medicaid. Also, anyone who had Medicare under the age of 65 years (n=215, 2.10% of the study population) were excluded from analyses as they do not represent the health of the general population. Those under Veterans Administration (n=129, 1.26% of the study population) were not included in the analyses. There were 597 missing observations in health and dental insurance variable that were also excluded from analyses. An exclusion bias analysis for the excluded observations was conducted for this study. Though the exclusion of these observations create a bias, however, justifications for the exclusions were provided to demonstrate that exclusions were necessary for the objective of the study. It should be noted that none of the observations were deleted, rather a single variable was created based on the exclusion criteria and domain analysis was carried out for the study sub-population using that variable to calculate correct standard errors as per CDC instructions found elsewhere.

The total sample size after all the exclusion criteria was 8966 observations (males, 4311; females, 4655). The sample definition process is explained in the figure 4.1 below.

Dependent Variable: Mortality

All-cause mortality was the dependent variable for this study. The month of death was made available along with the person month of follow up from the date of

examination. The mortality variable was a dichotomous variable as either assumed deceased or alive. Persons ineligible for mortality follow up were deemed missing. As the mortality rate is different between males and females, the analyses were conducted separately in males and females.

Independent Variable: Decayed Teeth

All the 28 permanent teeth among adults aged 20 years and above were examined by trained dentists in NHANES III. If the tooth was healthy and free of dental decay on any surface of the tooth, it was labelled as a sound tooth. If there was dental decay spotted on any surface of the tooth, it was labelled as decayed. Third molars (wisdom teeth) were excluded from our analyses as the presence of these teeth depend on several factors like different timings of eruption in lifetime of an individual, congenitally missing, or surgical extraction.

The number of decayed teeth was summed to represent a total number of untreated decayed teeth per person. The maximum value for decayed teeth that a person could have attained was 28 (all carious teeth) and the minimum value 0 (no carious tooth) but the actual score depended on the total number of teeth in the mouth of a person. As mentioned in the exclusion criteria, edentulous in one or both the jaws were excluded from the study, therefore, all the sampled persons in this study had 28 or less teeth.

The variable decayed teeth (DT) composed of the total sum of all the decayed teeth was continuous in nature, which was then categorized based on the distribution of decayed teeth in the sampled population. The description of the level of categories varied between males and females depending upon the distribution of dental decay in the

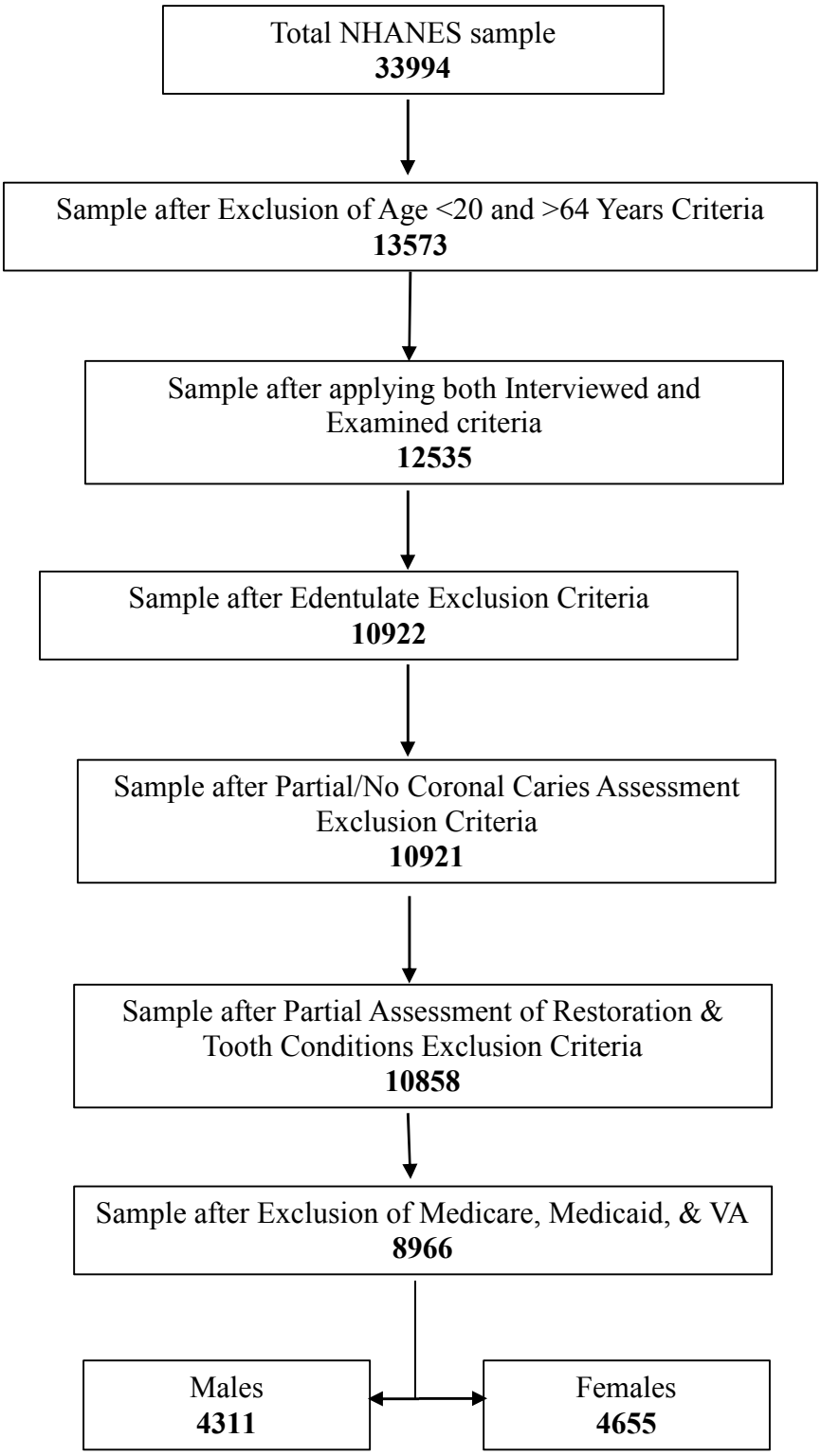

Fig. 4. 1 Schematic diagram of the Exclusion Criteria

respective population. Decayed teeth (DT) had three levels with no untreated carious tooth in a person's mouth (the referent level), 1 carious tooth, and 2-23 carious teeth for males and females. To create the levels, we looked at the distribution of decayed teeth category within each gender and based on it, there were three levels for DT category among males and females: the first level had no untreated decayed tooth (50% of the population distribution), the second level had 1 untreated decayed tooth (25% of population distribution) while the third level had 2-23 untreated decayed teeth (25% of population distribution).

Dental Insurance – Moderating Variable:

Dental insurance variable had three levels. Dental Coverage with Health Insurance, Only Health Insurance, and Uninsured. There were two different questions that were asked from respondents during NHANES III data collection for dental coverage. During the first phase, it was asked "is the person covered by health insurance that pays any part of dental care?" The answer to this question included any source of dental coverage, both public (Medicaid and Medicare) and private (Employer or Union). In all the phases, it was asked, "During the last month was [sample person] covered by one or more health insurance plans obtained privately or through an employer or union?" If it was answered "Yes", the respondent was then asked in the second, third, and fourth phases, "Did any of these plans cover any part of dental care?" making the dental coverage variable as being offered by an employer or union as a fringe benefit to health insurance. In order to match the question for dental coverage from any source in phase 1, it was matched to the question that was asked in second, third, and fourth phases of NHANES III data collection. Therefore, the dental coverage question for phase 1 "is the

person covered by health insurance that pays any part of dental care?" was matched with the question "During the last month was [sample person] covered by one or more health insurance plans obtained privately or through an employer or union?" to make dental coverage variable being offered by an employer or union, and any other source of dental coverage (Medicaid and Medicare) was coded as being not offered any dental coverage.

Anderson's Model of Healthcare Utilization

This study was conducted using the Andersen's model of healthcare utilization. Andersen (1995) modified the behavioral model of health care service utilization for the development of health policies to allow equitable access. The author described the model in four major categories; Pre-disposing characteristics that make up the demographics, social structure, and health beliefs to shape the need for health services. Enabling resources were the characteristics and vehicles that enable a person to obtain healthcare services. Need characteristics are the actual and perceived health, and those that are represented by the patient's health behaviors to obtain health services. Outcome is the result of all the three characteristics discussed, which is the improvement or deterioration in health, or mortality.

All variables were categorical in nature and were grouped according to the concepts proposed by Andersen (1995). Pre-disposing characteristics included race/ethnicity, marital status, education, family size, language of interview, rurality, and Census region variables. Race/ethnicity was categorized as non-Hispanic Whites (referent level), non-Hispanic Blacks, Mexican-Americans, and Others. Marital status had Never Married (referent level), Married, and Widowed/Separated/Divorced levels. Education variable was defined as having College degree or above (referent level), High school

diploma, and less than a high school education. Family size variable was composed of family having 1-2 individuals (referent level), a family of 3-4 individuals, and a family of 5 or more individuals. Language of interview was used as a proxy variable to gauge the ability of an individual to obtain information for dental and health insurance, and the ability to communicate for obtaining healthcare services. It had two levels: English (referent level) and Spanish/Other language of interview. Rurality was defined at the county level on the basis of USDA classification codes. It was pre-defined by NCHS as Urban (referent level) and Rural areas. This variable acted as a proxy variable for dental health professional shortage area. Census region was pre-defined by NCHS into four levels as North-East, Midwest, South, and West.

Enabling resources included Dental Visits and Federal Poverty Level (FPL). Dental visits had three levels: Regular Dental Visits (referent level), which was defined as those who visited regularly at least once a year or every two years. Episodic Dental Visits was defined as those who visited episodically as less often than every two years, whenever needed, and other or doesn't go anymore. Never visited a dentist were those who never went to a dentist in their lifetime. FPL was categorized into four levels as Less than 100% of FPL for those having a family to poverty ratio of less than 1. 100% to less than 200% FPL as those having a family to poverty ratio of 1 to less than 2. 200% of more of FPL (referent level) were those whose family to poverty ratio was 2 and above. Missing were those whose income was not declared by the respondents. This non-interpretable variable was created to prevent the loss of a big number of observations.

Need characteristics included Charlson's co-morbidity index, self-rated health status, and self-rated dental health status. Charlson's co-morbidity index was created

based on the guidelines provided by Charlson et al. (1987). It had four levels: Score of 0 meant that the respondent had no chronic disease. Score of 1 meant that the respondent had only one chronic disease. Score of 2 meant that the respondent had two chronic diseases and was at higher risk of mortality. Score of 3 or more meant three or more chronic diseases and at the highest risk of mortality in our study. Self-Rated Health Status and Self-Rated Dental Health Status were re-categorized into two levels as: Excellent/Very Good/Good and Fair/Poor Health and Dental Health Status.

Behavioral factors were four in this study: Alcohol use, Tobacco use, Body Mass Index (BMI), and Physical Activity. Alcohol had been known to contribute to dental caries (Sakki et al., 1994; Jansson, 2008; Kantorski et al., 2007; Eric Zaremski, 2012; Rooban et al., 2011) and increased the risk of mortality (Klatsky et al., 1992; Di Castelnuovo A et al., 2006). Any form of tobacco use is also a known risk factor for dental caries (Rooban et al., 2011; Benedetti et al., 2013; Golpasand Hagh et al., 2013) and mortality (Health, n.d.; Carter et al., 2015). Obesity leads to bad dental health (Prpić et al., 2012; Yuan et al., 2012) and mortality ("WHO | 10 facts on obesity," n.d.). Alcohol use had three levels: Current Drinker was defined as the respondent who had had at least 12 alcoholic beverages in the past one year at the time of survey. Former Drinker was the respondent who didn't have had any alcoholic beverage during the past one year but had at least 12 drinks in lifetime at the time of survey. Never Drinker were those who never had any alcoholic beverage in lifetime at the time of survey. Tobacco use had three levels too: Current Tobacco User was the respondent who actively used any form of tobacco product (cigarette, pipe, cigar, snuff, chewing tobacco) at the time of survey. Former Tobacco User was the respondent who smoked at least 100 cigarettes in his/her lifetime

but did not actively smoke cigarettes, or did not actively smoke 20 cigars or 20 pipes of tobacco, or did not use tobacco in any other form (snuff and chewing tobacco) at the time of survey but had used all these products in his/her lifetime at the time of survey. Never Tobacco User was the respondent who never smoked 100 cigarettes in life, and never smoked 20 cigars or 20 pipes of tobacco, and never used tobacco in any other form (snuff and chewing tobacco) at the time of survey. BMI had three levels: Normal/Underweight (less than 25.00 kg/m^2), Overweight (25.00 kg/m^2 – <30.00 kg/m^2), and Obese (30.00 kg/m^2 or more). Physically active was a dichotomous variable: "Yes" and "No". Yes was defined as a person who performed any of the physical activity (walked or biked in the past 30 days, did any task around home/yard for at least 10 minutes during the past 30 days, did any moderate or vigorous activity over the past 30 days for at least 10 minutes, did any muscle strengthening over the past 30 days) at the time of survey. No was defined as a person who did not perform any of these physical activities during the past 30 days at the time of survey.

Statistical Analyses:

Descriptive statistics were obtained for all the variables. Bivariate statistics were also obtained with chi-square values between independent variable, Pre-Disposing, Enabling, Need, and confounding variables. All statistical analyses were conducted in SAS v9.4 adjusting for the complex sampling techniques using weights, strata, and cluster variable to reflect the national population of U.S.

Propensity Score Analysis:

Private dental insurance with health insurance is significantly disproportionately distributed among various demographics and enabling factors (Table 4.1). In order to

compensate for this differential distribution of private dental coverage, we used propensity score method as proposed by Rosenbaum & Rubin (1983). Separate propensity scores were obtained for each gender, to parallel the mortality analysis.

In this study, the propensity score was obtained to address the differential probability of having private dental coverage with health insurance. This score was computed on an individual level without survey weights utilizing individual characteristics (race, education, marital status, total number of household, federal poverty level, language of interview) laid out in the multinomial logistic regression. The probabilistic scores computed by this technique reflected the likelihood of having private dental coverage with health insurance. The continuous probabilistic score that was created through this probabilistic logistic regression analysis was converted into a categorical variable based on the quartile distribution of the unweighted population. The four level categorical probabilistic score that was created, was used as a covariate (Rubin, 1997) in multivariate regression analyses to control for the differential probability of having private dental coverage.

Survival / Mortality Analyses:

Incremental models were developed in six stages to observe the effect on the risk of mortality by the addition of set of factors based on Andersen's model of healthcare utilization. The analyses were separated based on gender due to the difference between the mortality rate between the two genders. A total of seven incremental models were run. The first model was a minimally adjusted model consisting of independent variable adjusted for age. Actual age of the sampled person was used in all the analyses. The second model was composed of independent variable, dental insurance and its

corresponding propensity score variable. The third model constituted the independent variable and all the enabling variables. The fourth model had the addition of pre-disposing variables to model 3. The fifth model had all the variables in models 3 and the need variables. The sixth model had all the variables in it; independent, enabling variables, pre-disposing variables, need, and confounding variables. The last model was composed of all the variables in the sixth model in addition to the interaction term between dental insurance variable and dental caries variable.

Results

Description of the population

Among males, about 9% of the sampled population had died of various causes as of Dec. 31st, 2011 (Table 4.2). About 12% of the male population had only untreated carious tooth, and 16.61% had 2-20 untreated carious teeth. Half of the population (51.73%) had private dental coverage with private health insurance, 30.28% had only private health insurance, and nearly 18% were uninsured. The propensity quartiles had uneven distribution after the application of sample weights with more males in the fourth (also the highest) quartile (33.87%), descending subsequently to the first quartile (see table 4.2). More than half of the male population had regular dental visits in the past, while 44.5% had episodic visits, and a small proportion (2.66%) had never visited a dentist in their lifetime.

Among females, about 7% of the sample population were recorded deceased as of Dec. 31st, 2011. While more than three-quarter of them had no untreated dental caries, 9.74% had only one untreated carious tooth, and about 12% had 2-20 untreated carious teeth. More than half of the female population (54.91%) had private dental coverage with private health insurance, 30.74% had only private health insurance, and 14.35% were

uninsured. Majority of the females lied in the third quartile (34%), followed by fourth quartile (30%), second quartile (22.54%), and first quartile (12.93%). Two-thirds of the female had regular dental visits (67.79%), 31.33% had episodic dental visits, and 0.8% never visited a dentist in their lifetime.

Factors associated with mortality (unadjusted analysis)

We assessed the relationship between all variables and mortality. Only those deceased are shown in the table 4.3, as this was the outcome of interest for the study. All the results were significant at $\alpha < 0.05$.

Among males, those who had no untreated carious teeth had lower death rate (7.60%) while there was no difference among those who had 1 or 2-23 untreated caries teeth. Fewer deaths were observed in those who had private dental coverage with health insurance (7.74), the highest death rate was among those who had health insurance only (11.40%) and uninsured had 8.47% of the death rate. There was no statistically significant difference between the propensity quartiles for private dental coverage. Similarly, no statistical difference was found among dental visits and federal poverty level (see table 4.3).

Among females, there was an ascending order of death rate from no untreated carious teeth (6.33%) to 1 untreated carious tooth (8.74%) to 2-23 untreated carious teeth (10.71%). Those who had private dental coverage had the lowest death rate (~6%), followed by uninsured (8.15), and those with private health insurance only (8.70%). There was a mixed result in the propensity quartiles for private dental coverage, the lowest death rate was in the fourth (highest) quartile (5.37%) while the highest death rate was among those in the second quartile (9.70%). There was no statistically significant

difference in the dental visits category. However, people with less than 100% of FPL and more than 200% of FPL had fewer deaths (5% and 6.31%) while those at 100%-200% FPL had the highest death rate (8.92%).

Cox-Proportional Hazard Models

As mentioned in the methodology section, we adopted incremental models technique to see the incremental effect of dental coverage on the risk of mortality with dental diseases. Separate analytical results are reported for males and females in table 4.4.

Males with 2-23 untreated decayed teeth had 1.52 times the risk of death after adjusting for all the variables. Private dental coverage with private health insurance was significant only in the second model of survival analysis, where those having private dental coverage had 0.66 less the risk of mortality than uninsured among those with untreated decayed teeth. Dental insurance variable was not significant in any of the models after it was adjusted for other enabling, pre-disposing, need, and behavioral variables. However, even after adjusting for dental insurance in the second model, risk of mortality among those with untreated decayed teeth, though lowered from the simplified model, did not fall below 1 (see table 4.4).

Among females, the risk of mortality was significant till the addition of pre-disposing factors in model 4, after which it became insignificant till the final model. Private dental coverage remained insignificant throughout. In propensity score variable, the second quartile was the only one in model 2 that had higher the risk of mortality explaining that those with a lower probability of having dental coverage had 1.75 times the risk of mortality than those in the higher quartile of having dental coverage (see table 4.5).

Discussion:

Private dental insurance did not mitigate the risk of mortality among those with untreated decayed teeth in both the genders. In both the genders, there were fewer deaths among those with no decayed teeth as compared to those with 2-23 decayed teeth, similarly fewer death were observed among those who had private dental coverage. However, in multivariate cox proportional model, the effect of having private dental insurance was insignificant, implying that private dental insurance has no effect on the risk of mortality in both the genders with untreated decayed teeth.

As noted by Freeman et al. (2008) that health insurance varies by depth of coverage, cost-sharing, and financial incentives to physicians. Information on the depth of dental coverage, cost-sharing, and whether the dentist had any incentive for the provision of various dental treatments. This information was not gathered by NHANES III survey. It is also noteworthy that private dental coverage was captured at a single point in time, and it was not known that the respondents continued to have dental coverage in the latter years of survey. Also, we did not have information in the survey if deceased respondents who reached and surpassed the age of 65 years in the latter years of survey continued to have private dental coverage.

We have seen among males that untreated decayed teeth had a higher risk of mortality in model 6 when we adjust for all the variables. Though private dental coverage was insignificant for the risk of mortality, therefore, it may not be needed to prolong life or prevent mortality in its current form where cost-sharing is a concern. There is a need for a study to see the effect on the risk of mortality where cost-sharing would not be a concern to the recipients of the dental services with untreated decayed teeth. For

example, in RAND HIE, better oral health outcomes were seen when cost-sharing was very limited or no cost-sharing as compared to those who had moderate, or high cost sharing. Moreover, dental insurance only mitigates the barrier of upfront costs and not the cost-sharing barrier (Thompson et al., 2014; Bendall & Asubonteng, 1995).

Another reason for increased risk of mortality among males with decayed teeth and no effect of private dental coverage on the risk of mortality could be the non-comprehensive nature of private dental insurance (Bhatti et al., 2007). Manski et al. (2002) stated that there are other determinants of dental care use in addition private dental insurance, also employer-sponsored dental coverage offered very little choice. Perceptions to need dental care also determines whether they visit a dentist or not, also even when people with low income and low education had dental insurance, they had lower odds of visiting a dentist (Millar & Locker, 1999).

Limitations

There are several limitations related to this study. First, it is a cross-sectional study and does not reveal causality. Private dental coverage was captured one point in time and it was not known if private dental coverage continued to be available for those after the end of survey.

Conclusions:

Private dental coverage does not lower the risk of mortality among those with untreated dental decay. Though, males with untreated dental decay had a higher risk of mortality, private dental coverage did not mitigate the effect of mortality even among them. Private dental insurance may have other virtues like preventive dental screening, teeth cleaning, etc., however, the best of the best dental benefits require out of pocket

costs even for preventive dental services. Future cohort research is needed to investigate the effects of zero cost-sharing dental insurance on the risk of mortality in the population.

Table 4. 1: Factors associated with reported private dental insurance among working age adults, 1988-1994 NHANES

n= 8966	For Age between 20 & 64 Years					
	Male (n = 4311)			Female (n = 4655)		
Variables	**%**	**SE**	**p-value**	**%**	**SE**	**p-value**
Pre-disposing Characteristics						
Race			<.0001			<.0001
Non-Hispanic White	54.28	2.17		56.65	1.92	
Non-Hispanic Black	54.51	2.26		59.36	2.41	
Mexican-American	33.02	1.49		35.85	2.01	
Others	39.08	5.84		43.29	5.5	
Marital			<.0001			<.0001
Married	57.11	1.91		57.35	1.72	
Widowed/Separated/Divorced	40.68	4.43		43.6	3.37	
Never Married	38.82	2.9		55.06	2.54	
Education			<.0001			<.0001
Less than High School	30.84	2.64		32.16	2.66	
High School	50.7	2.22		53.46	2.25	
College Degree or More	58.92	2.22		62.11	2.3	
Federal Poverty Level			<.0001			<.0001
Less than 100% FPL	18.7	2.99		27.7	4.15	
100% to less than 200% FPL	31.59	3.15		37.8	2.58	
More than 200% FPL	61.1	1.95		63.16	1.91	
Missing	35.12	5.67		39.37	5.28	
Family size			0.015			0.0004
1-2 Family Members	49.22	2.64		55.34	2.44	
3-4 Family Members	55.86	2.27		55.62	2.13	
5 or more family members	47.1	3.17		51.85	2.71	
Enabling Factors						
Dental Visits			<.0001			<.0001
Regular	62.84	1.96		63.45	1.82	
Episodic	40.09	2.19		37.32	2.01	

Never	26.78	7.85		24.92	6.21	
Language of Interview			<.0001			<.0001
English	53.73	1.8		56.58	1.63	
Spanish/Other	19.64	3.53		19.2	3.91	
Rurality			0.0037			0.0056
Urban	55.95	2.29		58.96	1.97	
Rural	47.04	2.49		50.73	2.84	
Region			0.0063			0.0008
North-East	56.67	5.05		57.76	3.61	
Mid-West	52.63	2.56		54.36	2.02	
South	48.19	2.98		50.31	2.45	
West	52.05	4.04		60.41	3.34	

Table 4. 2 Characteristics of population studied, working age adults, 1988-1994 NHANES

N = 8966	Male (n = 4311)		Female (n = 4655)	
Variables	**%**	**SE**	**%**	**SE**
Dependent Variable				
Mortality				
Alive	91.02	0.56	92.90	0.51
Deceased	8.98	0.56	7.10	0.51
Independent Variable				
Decayed Teeth Categories				
No Untreated Carious teeth	71.26	1.30	77.98	1.27
1 Untreated Carious tooth	12.12	0.75	9.74	0.74
2-20 Untreated Carious Teeth	16.61	1.10	12.28	0.84
Enabling Factors				
Dental Coverage				
Dental Coverage with Health Insurance	51.73	1.75	54.91	1.55
Pvt. Health Insurance	30.28	1.58	30.74	1.54
Uninsured	17.99	1.40	14.35	1.09
Propensity Quartiles				
First	11.82	0.88	12.93	1.11
Second	22.79	0.98	22.54	0.96
Third	31.52	1.27	34.13	1.21
Fourth	33.87	1.34	30.40	1.30
Dental Visits				
Regular	52.83	1.53	67.79	1.34
Episodic	44.51	1.62	31.33	1.33
Never	2.66	0.43	0.88	0.17
Federal Poverty Level				
Less than 100% FPL	7.70	0.75	7.99	0.81
100% to less than 200% FPL	16.30	0.87	16.93	0.99
200% or more FPL	71.01	1.20	70.33	1.22
Missing	4.99	0.57	4.76	0.35
Pre-disposing Characteristics				
Race				
Non-Hispanic White	76.11	1.39	77.00	1.20
Non-Hispanic Black	9.51	0.58	10.63	0.77

Mexican-American	6.38	0.60	5.11	0.46
Others	7.99	1.05	7.26	0.81
Marital				
Married	69.84	1.16	68.87	1.33
Widowed/Separated/Divorced	7.44	0.57	14.99	0.84
Never Married	22.72	1.37	16.14	1.04
Education				
Less than High School	16.65	1.02	13.77	0.91
High School	31.08	1.28	35.70	1.31
College Degree or More	52.27	1.63	50.53	1.58
Family size				
1-2 Family Members	40.61	1.58	41.49	1.37
3-4 Family Members	42.99	1.31	42.71	1.17
5 or more family members	16.40	0.91	15.79	0.80
Language of Interview				
English	94.12	0.86	95.61	0.56
Spanish/Other	5.88	0.86	4.39	0.56
Rurality				
Urban	52.62	4.78	50.74	4.88
Rural	47.38	4.78	49.26	4.88
Region				
North-East	19.67	1.14	19.85	1.56
Mid-West	23.43	1.27	23.06	1.42
South	35.41	2.90	35.45	2.95
West	21.49	3.41	21.64	3.83
Need Variables				
Charlson Co-morbidity Index				
Score of 0	85.23	0.79	79.46	0.87
Score of 1	10.01	0.58	11.22	0.67
Score of 2	3.34	0.51	7.55	0.53
Score of 3 or more	1.42	0.25	1.78	0.24
Self-Rated Health Status				
Excellent/Very Good/Good	92.21	0.53	89.62	0.64
Fair/Poor	7.79	0.53	10.38	0.64
Self-Rated Dental Health Status				
Excellent/Very Good/Good	69.26	1.29	72.04	1.25
Fair/Poor	30.74	1.29	27.96	1.25
Behavioral Factors				
Alcohol				

Current Drinker	73.52	1.44	51.36	1.60
Former Drinker	21.32	1.22	33.34	1.12
Never Drinker	5.15	0.56	15.30	0.93
Tobacco Use in any Form				
Current User of Tobacco Products	37.63	0.97	24.45	1.10
Former User of Tobacco Products	29.03	1.13	18.53	0.76
Never Used Tobacco Products	33.34	1.13	57.03	1.29
BMI				
Normal Weight/Underweight	42.03	1.11	54.17	1.38
Overweight	40.22	1.14	23.58	1.02
Obese	17.75	0.82	22.25	1.14
Physical activity				
Yes	91.73	0.85	86.94	0.92

Table 4. 3 Percent deceased by 2011, working age adults, by personal characteristics, 1988-1994 NHANES

N = 8966	Male (N=5074)			Female (n = 4655)		
Variables	**%**	**SE**	**p-value**	**%**	**SE**	**p-value**
Independent Variables						
Decayed Teeth Categories			0.0004			
No Untreated Carious teeth (50% sample)	7.60	0.68				
1 Untreated Carious teeth (25% of sample)	12.05	1.55				
2-23 Untreated Carious Teeth (25% of sample)	12.61	1.57				
Decayed Teeth Categories						0.0182
No Untreated Carious teeth (50% sample)				6.33	0.59	
1 Untreated Carious teeth (25% of sample)				8.74	1.77	
2-23 Untreated Carious Teeth (25% of sample)				10.71	1.85	
Enabling Factors						
Dental Coverage			0.024			0.0256
Dental Coverage with Health Insurance	7.74	0.78		5.93	0.54	
Pvt. Health Insurance	11.40	1.23		8.70	1.07	
Uninsured	8.47	1.22		8.15	1.41	
Propensity Score for Dental Coverage			0.8391			0.0038
First Quartile	8.65	1.33		8.05	0.91	
Second Quartile	8.65	0.97		9.70	1.15	
Third Quartile	9.59	1.15		6.60	0.89	
Fourth Quartile	8.61	0.74		5.37	0.80	
Dental Visits			0.3877			0.0604
Regular	8.94	0.84		6.38	0.56	
Episodic	9.28	0.71		8.44	0.98	
Never	5.17	1.95		12.56	5.99	
Federal Poverty Level			0.1556			<.0001
Less than 100% FPL	12.05	2.16		5.05	0.75	
100% to less than 200% FPL	8.23	0.71		8.92	1.31	
More than 200% FPL	8.66	0.70		6.31	0.63	
Missing	11.27	2.48		15.96	3.11	

Pre-disposing Characteristics						
Race			0.009			0.1874
Non-Hispanic White	8.74	0.76		7.02	0.64	
Non-Hispanic Black	13.50	1.11		9.25	0.79	
Mexican-American	8.67	0.79		6.02	0.65	
Others	6.13	1.92		5.61	1.88	
Marital			0.0002			0.0003
Married	9.72	0.56		6.76	0.65	
Widowed/Separated/Divorced	13.01	1.96		12.02	1.68	
Never Married	5.38	1.08		3.83	1.13	
Education			0.0005			<.0001
Less than High School	12.39	1.27		12.16	1.79	
High School	9.65	0.84		7.58	0.76	
College Degree or More	7.37	0.75		5.37	0.71	
Family size			0.0007			0.0012
1-2 Family Members	11.83	1.20		9.27	0.81	
3-4 Family Members	7.20	0.80		5.01	0.69	
5 or more family members	6.54	1.15		7.04	1.45	
Language of Interview			0.3141			0.0649
English	9.10	0.60		7.22	0.55	
Spanish/Other	7.25	1.52		5.03	0.82	
Rurality			0.3168			0.0564
Urban	8.40	0.57		6.19	0.72	
Rural	9.62	1.06		8.04	0.68	
Region			0.2651			0.6244
North-East	10.09	1.36		6.89	1.42	
Mid-West	9.19	1.23		7.20	0.33	
South	9.44	1.03		7.79	1.08	
West	6.95	0.84		6.06	0.80	
Need Variables						
Charlson Co-morbidity Index			<.0001			<.0001
Score of 0	7.13	0.57		5.28	0.48	
Score of 1	16.20	2.41		12.01	1.91	
Score of 2	20.84	4.22		14.50	3.13	
Score of 3 or more	40.62	8.50		25.96	5.86	
Self-Rated Health Status			<.0001			<.0001
Excellent/Very Good/Good	7.77	0.61		6.03	0.57	
Fair/Poor	23.17	2.71		16.35	2.47	

Self-Rated Dental Health Status			<.0001			0.002
Excellent/Very Good/Good	7.20	0.67		6.05	0.58	
Fair/Poor	12.94	0.94		9.79	1.15	
Confounding Factors						
Alcohol			0.1301			0.1149
Current Drinker	8.35	0.81		6.20	0.89	
Former Drinker	11.43	1.15		8.78	1.06	
Never Drinker	8.12	2.56		6.43	1.00	
Tobacco Use in any Form			<.0001			<.0001
Current User of Tobacco Products	11.09	1.02		10.38	1.16	
Former User of Tobacco Products	10.60	1.08		8.69	1.51	
Never Used Tobacco Products	5.19	0.68		5.17	0.49	
BMI			<.0001			<.0001
Normal Weight/Underweight	7.60	0.67		4.62	0.58	
Overweight	7.77	0.96		8.53	1.06	
Obese	15.04	1.64		11.63	1.50	
Physical activity			0.0162			0.027
Yes	8.63	0.57		6.78	0.56	
No	12.80	1.95		9.25	1.09	

Table 4. 4 Mortality risk among males of working-age, 20-64 years, with untreated dental decay

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
	Male	Male	Male	Male	Male	Male
Variables	HR	HR	HR	HR	HR	HR
Independent Variable						
Age	1.09	1.09	1.09	1.09	1.08	1.09
Decayed Teeth Categories						
No Untreated Carious teeth	Referent Variable	Referent Variable	Referent Variable	Referent Variable	Referent Variable	Referent Variable
1 Untreated Carious tooth	1.72*	1.63*	1.54*	1.46*	1.41*	1.32
2-20 Untreated Carious Teeth	2.11*	1.89*	1.78*	1.65*	1.62*	1.52*
Enabling Factors						
Dental Coverage						
Uninsured		Referent Variable	Referent Variable	Referent Variable	Referent Variable	Referent Variable
Dental Coverage with Health Insurance		0.66*	0.72	0.71	0.82	0.86
Pvt. Health Insurance		0.82	0.88	0.85	0.94	0.94
Propensity Score for Dental Coverage						
Fourth Quartile		Referent Variable	Referent Variable	Referent Variable	Referent Variable	Referent Variable
First Quartile		1.28	0.64	0.44	0.47	0.52
Second Quartile		1.30	0.99	0.68	0.67	0.68
Third Quartile		1.09	1.07	0.87	0.87	0.87
Dental Visits						

Never			Referent Variable	Referent Variable	Referent Variable	Referent Variable
Regular			1.46	1.41	1.46	1.27
Episodic			1.19	1.18	1.22	1.12
Federal Poverty Level						
More than 200% FPL			Referent Variable	Referent Variable	Referent Variable	Referent Variable
100% to less than 200% FPL			1.33	1.49	1.36	1.38
Less than 100% FPL			2.52	2.86	2.63	2.56
Missing			1.27	1.50	1.58	1.59
Pre-disposing Characteristics						
Race						
Non-Hispanic White				Referent Variable	Referent Variable	Referent Variable
Non-Hispanic Black				1.40	1.37	1.38
Mexican-American				1.46	1.43	1.46
Others				0.83	1.02	0.91
Marital						
Never Married				Referent Variable	Referent Variable	Referent Variable
Married				0.76	0.72	0.69
Widowed/Separated/Divorced				0.75	0.77	0.71
Education						
College Degree or More				Referent Variable	Referent Variable	Referent Variable
High School				1.40	1.35	1.27
Less than High School				1.41	1.18	1.02
Family size						

1-2 Family Members				Referent Variable	Referent Variable	Referent Variable
3-4 Family Members				0.71	0.79	0.81
5 or more family members				0.63	0.59	0.56
Language of Interview						
English				Referent Variable	Referent Variable	Referent Variable
Spanish/Other				0.79	0.77	0.85
Rurality						
Urban				Referent Variable	Referent Variable	Referent Variable
Rural				1.14	1.09	1.10
Region						
North-East				Referent Variable	Referent Variable	Referent Variable
Mid-West				0.84	0.77	0.75
South				0.83	0.71	0.69
West				0.68	0.60	0.56
Need Variables						
Charlson Co-morbidity Index						
Score of 0					Referent Variable	Referent Variable
Score of 1					2.08	2.09
Score of 2					1.60	1.61
Score of 3 or more					3.18	2.81
Self-Rated Health Status						
Excellent/Very Good/Good					Referent Variable	Referent Variable

Fair/Poor					2.16	2.04
Self-Rated Dental Health Status						
Excellent/Very Good/Good					Referent Variable	Referent Variable
Fair/Poor					1.27	1.25
Confounding Factors						
Alcohol						
Never Drinker						Referent Variable
Current Drinker						1.01
Former Drinker						0.87
Tobacco Use in any Form						
Never Used Tobacco Products						Referent Variable
Current User of Tobacco Products						1.69
Former User of Tobacco Products						1.15
BMI						
Normal Weight/Underweight						Referent Variable
Obese						1.26
Overweight						0.83
Physical activity						
No						1.31

*** = significant at α.05**

Table 4. 5 Mortality risk among females of working-age, 20-64 years, with untreated dental decay

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
	Male	Male	Male	Male	Male	Male
Variables	HR	HR	HR	HR	HR	HR
Independent Variable						
Age	1.09	1.09	1.09	1.09	1.08	1.09
Decayed Teeth						
No Untreated Carious teeth	Referent Variable	Referent Variable	Referent Variable	Referent Variable	Referent Variable	Referent Variable
1-2 Untreated Carious teeth	1.41	1.31	1.21	1.22	1.09	1.06
3-23 Untreated Carious Teeth	2.29*	1.96*	1.73*	1.60*	1.48	1.47
Enabling Factors						
Dental Coverage						
Uninsured		Referent Variable	Referent Variable	Referent Variable	Referent Variable	Referent Variable
Dental Coverage with Health Insurance		0.81	0.87	0.81	0.79	0.83
Pvt. Health Insurance		0.77	0.81	0.75	0.76	0.84
Propensity Score for Dental Coverage						
Fourth Quartile		Referent Variable	Referent Variable	Referent Variable	Referent Variable	Referent Variable
First Quartile		1.45	1.35	1.12	1.01	1.11
Second Quartile		1.75*	1.44	1.12	1.07	1.10
Third Quartile		1.10	1.07	0.92	0.87	0.85
Dental Visits						

Never			Referent Variable	Referent Variable	Referent Variable	Referent Variable
Regular			0.57	0.54	0.59	0.87
Episodic			0.42	0.40	0.46	0.74
Federal Poverty Level						
More than 200% FPL			Referent Variable	Referent Variable	Referent Variable	Referent Variable
100% to less than 200% FPL			1.17	1.19	1.15	1.07
Less than 100% FPL			0.72	0.71	0.65	0.62
Missing			1.44	1.56	1.50	1.42
Pre-disposing Characteristics						
Race						
Non-Hispanic White				Referent Variable	Referent Variable	Referent Variable
Non-Hispanic Black				1.04	0.99	0.96
Mexican-American				0.96	0.96	1.02
Others				0.89	0.92	1.03
Marital						
Never Married				Referent Variable	Referent Variable	Referent Variable
Married				0.69	0.70	0.61
Widowed/Separated/Divorced				0.83	0.84	0.69
Education						
College Degree or More				Referent Variable	Referent Variable	Referent Variable
High School				1.08	1.09	1.08
Less than High School				1.21	1.19	1.07

Family size						
1-2 Family Members				Referent Variable	Referent Variable	Referent Variable
3-4 Family Members				0.89	0.86	0.92
5 or more family members				1.27	1.29	1.36
Language of Interview						
English				Referent Variable	Referent Variable	Referent Variable
Spanish/Other				0.57	0.49	0.62
Rurality						
Urban				Referent Variable	Referent Variable	Referent Variable
Rural				1.21	1.18	1.18
Region						
North-East				Referent Variable	Referent Variable	Referent Variable
Mid-West				0.96	0.99	1.00
South				0.97	0.95	1.07
West				0.94	0.90	0.97
Need Variables						
Charlson Co-morbidity Index						
Score of 0					Referent Variable	Referent Variable
Score of 1					1.95	1.76
Score of 2					1.87	1.66
Score of 3 or more					2.14	1.99
Self-Rated Health Status						

Excellent/Very Good/Good					Referent Variable	Referent Variable
Fair/Poor					1.60	1.55
Self-Rated Dental Health Status						
Excellent/Very Good/Good					Referent Variable	Referent Variable
Fair/Poor					1.09	0.99
Confounding Factors						
Alcohol						
Never Drinker						Referent Variable
Current Drinker						1.42
Former Drinker						1.25
Tobacco Use in any Form						
Never Used Tobacco Products						Referent Variable
Current User of Tobacco Products						2.25
Former User of Tobacco Products						1.19
BMI						
Normal Weight/Underweight						Referent Variable
Obese						1.85
Overweight						1.33
Physical activity						
No						0.92

*= Significant at α 0.05

CHAPTER 5

THE EFFECT OF DENTAL COVERAGE ON THE ASSOCIATION OF PERIODONTITIS & MORTALITY AMONG WORKING AGE U.S. ADULTS[2]

[2]Sadiq, N., Probst, J.C., Martin, A.B., Khan, M., Merchant, A.T. To be submitted to the Journal of Dental Research

Abstract

Purpose: The purpose of this paper was to assess the mitigating effect of private dental insurance on mortality risk of work-age adults with periodontitis. **Methods:** NHANES III dataset was used that was linked to mortality data that was updated through Dec. 31st, 2011. Though NHANES III used partial mouth protocol that underestimates prevalence and it was recommended to use NHANES 2009-2010, however, fewer number of deaths make it unusable for mortality analysis. All analyses were run by SAS v9.4. Complex sampling method was considered along with weighting to represent the national population. The multivariate analyses were adjusted for the propensity score to adjust for differential distribution of private dental insurance in the population. **Results:** Males had the second highest death rate while females had the lowest death rate in unadjusted analyses of private dental insurance. Both males and females had the highest death rate among those with moderate/sever periodontitis. **Conclusions:** Provision of private dental coverage did not help in reducing the risk of death among working-age adults with periodontitis. There could be factors other than financial barriers that could be responsible for insignificant effect of private dental insurance in this population.

INTRODUCTION

Diseased gums lead to several oral and systemic problems, the most prominent of which is the periodontitis. Periodontitis is a chronic inflammatory disease caused by infection of the supporting tissues around the teeth (Page, Eke, 2007). Periodontitis starts with the formation of dental plaque (Kinane, 1999) when not removed by mechanical means over long time, though the response time for periodontitis varies with individuals. Periodontitis has been linked to several systemic diseases like cardiovascular diseases,

cerebrovascular diseases, kidney ailments, and diabetes (Li et al., 2000; Meurman et al., 2004; Jansson et al., 2002; Jansson et al., 2001; Awano et al., 2008; Weidlich et al., 2008; Debelian et al., 1994). It is known that poor oral health causes morbidity and in some cases mortality (Kim et al., 2013; Navazesh & Mulligan, 1995; Jansson et al., 2002) as a bad oral cavity has effects on the whole body (Benjamin, 2010). Three pathways have been identified through which oral infections spread to cause various systemic diseases: circulation of bacterial toxins, bacteremia, and immunological injury caused by oral bacteria (Li et al., 2000). Therefore, preventive and curative dental services are very important for early diagnosis and in-time treatment of the patients with periodontitis.

The overall prevalence of overall periodontitis in adults ages 30 years and above was 47% during 2009-2010 NHANES using 4 out of 6 sites in full-mouth protocol examination (FMPE), 8.7% for mild periodontitis, 30% for moderate, and 8.5% for severe periodontitis (Eke, Dye, et al, 2012). According to the authors, males had the highest proportion of periodontitis. Among other characteristics, being Mexican-American, current smokers, living 100% below the federal poverty level (FPL), and having less than a high school diploma was associated with a higher rate of periodontitis.

According to Bloom and Cohen (2010), primary access to dentists is determined by dental insurance. The major source of dental coverage is either private or through employer (Manning et al., 1985), while dental coverage by Medicaid is highly limited or does not exist (Bloom & Cohen, 2010; Singhal et al., 2015) and when provided, most Medicaid plans do not cover periodontal treatment. About 73% of the US population aged less than 65 years had dental coverage in some form (Bloom & Cohen, 2010) in the year 2008.

Xu & Lu, (2011) conducted a study using NHANES III data and linked with respective mortality file to see the effects of periodontitis on the risk of death. The authors found that the risk of death was more among men aged 30-64 years, however, the control variables in their study were limited and periodontitis was not defined according to the criteria laid out by Eke et al., 2012). This paper addressed the gaps in the study by Xu and Lu (2011) and also examines the role of dental coverage. The purpose of this paper was to see the mitigating effect of dental insurance on the risk of mortality among working age adults with total periodontitis.

Methodology

This study used Andersen's Behavioral Model of Health Services (Andersen, 1995) to assess the relationship of dental insurance on total periodontitis and mortality. To answer the research question, data were drawn from public-use NHANES III 1988-1994 dataset and linked, through respondent's unique identification number, with mortality data that was followed through December 31st, 2011. NHANES III is a complex, multi-stage sample of the non-institutionalized population of U.S. conducted by National Center for Health Statistics (NCHS). More details on sampling techniques and data collection could be found elsewhere (CDC, 1996). All the analyses were separated for gender as the mortality rate vary for both males and females and the significance level for all the results was set at $\alpha = .05$

Inclusion & Exclusion criteria

This study included only those respondents who completed both interview and examination. Furthermore, data were restricted to those who fell in the age range of 20-64 years. As periodontal measurements could not be taken among those who had certain medical conditions, specific heart problems and conditions that might require antibiotics

before a dental examination, analyses were further restricted to all those who did not have any medical condition (NHANES III did not collect data on those having certain medical conditions like heart problems and those conditions that required a prophylactic antibiotic administration prior to dental examination) and to those who had a complete periodontal assessment of the loss of attachment and probing depth. Edentulous persons were also excluded from the study because periodontitis exists in mouths with teeth. In order to avoid competing risks, those who had root caries were also excluded from the final sample. Figure 1, below, displays step by step criteria that lead to the attainment of final sample. Note that the observations were not deleted to get the final sample size but a new variable was created that satisfied the exclusion criteria to be used in domain statement of SAS to avoid incorrect estimation of standard errors as per directions from CDC.

Methodological Challenge of Using a Half-Mouth Protocol for Periodontitis

NCHS used a partial mouth protocol examination (PMPE) to record periodontal measurements instead of a full-mouth protocol examination (FMPE) in NHANES III. PMPE uses two random quadrants taking measurements from two sites per tooth (one inter-proximal and one mid-buccal site) as opposed to FMPE where the measurement from all the six sites (four inter-proximal and two mid-facial/lingual sites) is taken from all the six teeth. In 2009, NCHS adopted a FMPE for the first time to record periodontal measurements (Eke et al., 2012), all previous were based on PMPE. PMPE leads to underestimation of periodontal prevalence in the population because periodontitis is not evenly distributed in the mouth (Kingman & Albandar, 2002; Kingman et al., 1988; Tran et al., 2013), though the prevalence of any disease is also influenced by the method

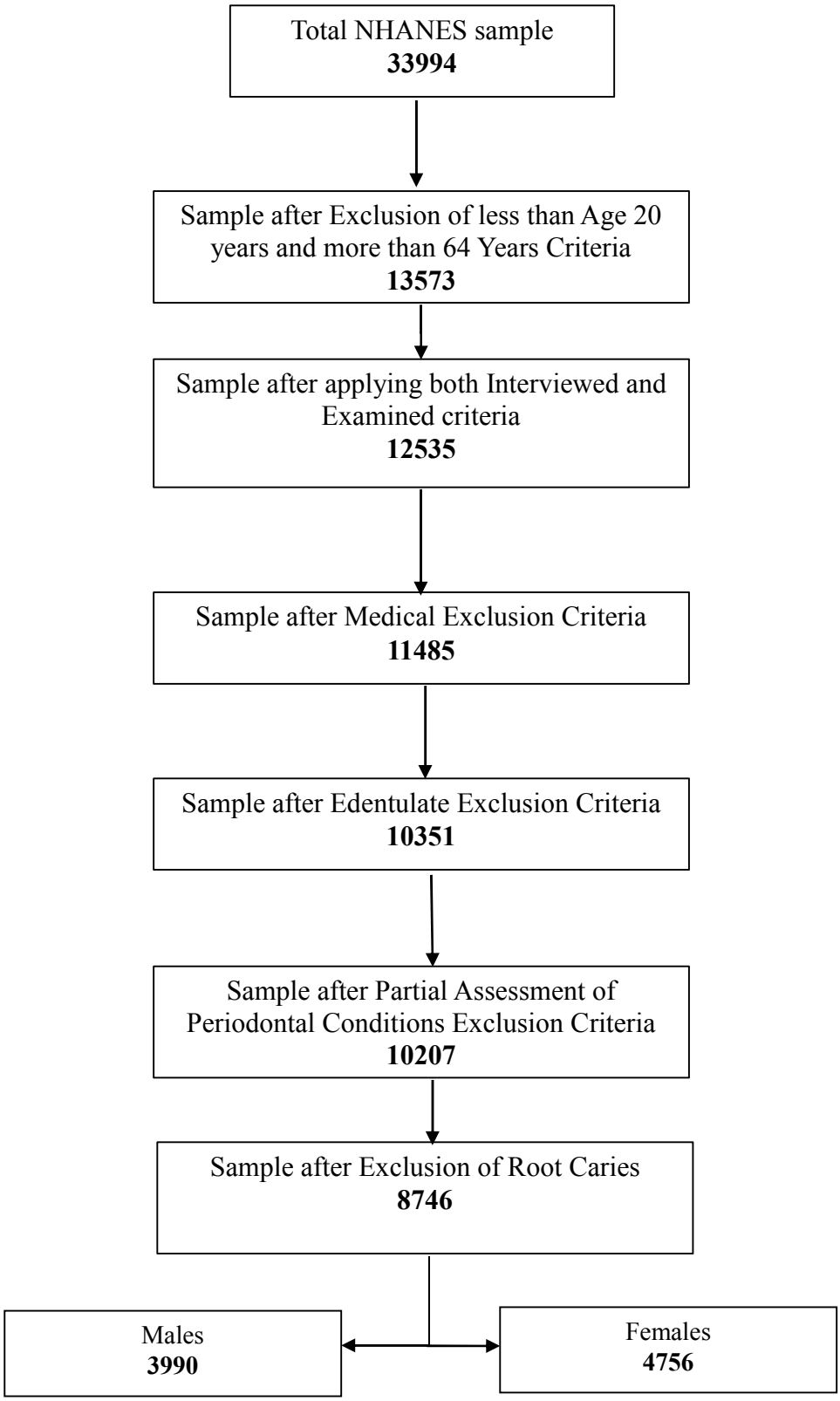

Fig. 5. 1 Exclusion Criteria Leading to Final Sample

it is defined (Eke et al., 2010). Eke et al., (2012) definition takes into account 4 out of 6 sites to define periodontitis, thus underestimating the true prevalence by about 8.8% (absolute bias) but with an overall sensitivity of 84.28% when compared to all six sites per tooth.

The underestimated prevalence with PMPE is a case of random misclassification, therefore, the direction of association will remain the same even with the adoption of FMPE except that the association will be greater for the true prevalence (Eke et al. 2010; Kingman et al., 2008). Thomson & Williams (2002) and Peres et al. (2012) showed in their studies that PMPE for periodontitis records sufficient information to measure the periodontal association with socio-demographics and behavioral factors. Though the use of FMPE in NHANES (2009-2010) would improve ability to detect the association of periodontitis with mortality, however, the current mortality file for this data set has relatively few observed deaths. In future, it is recommended that NHANES (2009-2010) be used to find the true association of periodontitis with mortality; at present, the earlier version of NHANES has better mortality experience. Several authors have published reports on the association of periodontal disease and systemic health. Taylor et al. (2000) using the NHANES III showed that periodontitis is an etiologic factor for type 2 diabetes and aspiration pneumonia. A recent study published by Lula et al. (2014) using NHANES III data showed that high frequency consumption of added sugars was associated with periodontal disease that could lead to other systemic diseases, using bleeding on probing and pocket depth of ≥ 3mm as a criteria for assigning periodontitis. Several other studies utilized NHANES III to observe the association of periodontitis with other systemic diseases used either probing depths ≥4mm or clinical attachment loss of ≥4mm or both

(Chapple et al., 2007; Tomar & Asma, 2000; Morita et al., 2009; Wood et al., 2003; Arbes et al., 1999; Albandar et al., 1999; Xu & Lu, 2011; Saremi et al., 2005). The positive association of periodontitis with systemic diseases has also been established by other studies that used datasets other than NHANES (Noble et al., 2014; Wowern et al., 1994; Elter et al., 2004).

Specificity & Sensitivity of Half/Partial Mouth Protocols

The specificity of PMPE is 100% when compared to FMPE, thus when PMPE records no periodontitis, FMPE also records no periodontitis, however, the sensitivity varies with case definitions and measurement methods (Eke et al., 2010). The sensitivity of NHANES III was 40% when compared to NHANES 2009-2010 (Eke et al., 2010). According to Eke et al. (2012) updated periodontal definitions, the sensitivity of detecting moderate periodontitis is 47.5% and that of severe periodontitis is 23.7% in a half-mouth exam with only one measured, Mesio-Buccal, inter-proximal site (Tran et al., 2014). In the present study, sensitivity to moderate and severe periodontitis is similarly low, potentially biasing findings towards the null.

NHANES III utilized PMPE protocol to measure periodontitis. Susin et al. (2005) demonstrated that a FMPE showed a higher sensitivity followed by Mesiobuccal - Buccal – Distobuccal (MB-B-DB) PMPE protocol, and Mesiobuccal - Buccal (MB-B) PMPE protocol (Tran et al., 2013). Though, NHANES 2001-2004 added DB site as an additional site for periodontal measurement, however, Susin et al. (2005) demonstrated that in three sites per tooth systems, sensitivities were better with DL (Disto-Lingual) site than with DB (Kingman et al., 2008). According to Tran et al. (2013), the use of 1999-2004 does not provide any added advantage except for NHANES 2009-2010 for the

measurement of periodontitis, therefore, for this study NHANES III will be used to observe the association of periodontitis with mortality instead of NHANES 1988-1994. NHANES 2009-2010 could not be used currently as the mortality file associated with it has very few observations (N=134 deaths) to obtain any statistically viable results. It will take about 6-7 years of mortality data collection to determine the true association of periodontitis with mortality in NHANES 2009-2010.

Measurement

Dependent Variable: Mortality

All-cause mortality was taken into account along with person-month of follow-up from the date of examination. The mortality variable was dichotomous in nature having two levels: assumed deceased or assumed alive. Those who were ineligible for mortality follow up were coded as missing.

Independent Variable: Total Periodontitis

Based on the definition laid out by Page & Eke (2007), total periodontitis was a dichotomous variable defined as a combined sum of moderate and severe periodontitis, while no periodontitis was a sum of no mild, moderate, or severe periodontitis. Page & Eke (2007) defined moderate and severe periodontitis as: Moderate periodontitis: "Two or more interproximal sites with clinical attachment loss of ≥ 4 mm, not on the same tooth, or two or more interproximal sites with pocket depth of ≥ 5 mm, not on the same tooth." Severe periodontitis: "Two or more interproximal sites with clinical attachment loss of ≥ 6 mm, not on the same tooth, and one interproximal site with pocket depth of ≥ 5 mm, not on the same tooth." Eke, Page, and Wei (2012) defined mild periodontitis as "two or more than two interproximal sites with clinical attachment loss of ≥ 3 mm and

two or more interproximal sites with pocket depth of ≥ 4 mm (not on same tooth), or one site with pocket depth of ≥ 5 mm." The rationale behind placing mild and no periodontitis together is that the effect of mild periodontitis on health is negligible. For the measurement of periodontitis, third molars were excluded due to their non-presence in the form of impaction, surgical extraction, or congenitally missing.

Dental Insurance – Moderating Variable:

This variable had three levels: Private dental coverage with health insurance, Private health insurance, and uninsured.

In NHANES III survey, two questions for dental coverage were asked in different phases:

(1) Only asked in phase 1: "Is the person is covered by health insurance that pays any part of dental care?"

(2) Asked in phases 2, 3, and 4: "Did any of these plans (private, or employer/union sponsored health plans) cover any part of dental care?"

In order to synchronize the dental coverage question 1 with question 2, we matched the question 1 with the question that asked "During the last month was [sample person] covered by one or more health insurance plans obtained privately or through an employer or union?" This way we created a dental coverage with health insurance variable offered privately, or through employer, or union.

Anderson's Model of Healthcare Utilization

Based on Andersen's model, there are three factors that are responsible for healthcare utilization. Enabling resources, pre-disposing, and need factors.

Enabling resources are the vehicles for obtaining healthcare services. Dental visits were used as a proxy measure for access dentists and dental hygienists. The dental visit

variable was dichotomous in nature, with those who had "regular visits" defined as visited regularly at least once a year or every two years, while "episodic visits" were defined as those who never visited, or visited less often than every two years, whenever needed, and other or doesn't go any more. Those who never visited and those who don't go anymore were placed in episodic visits due to few numbers of observations.

For family poverty ratio, 5% of the observations were missing. Bias resulting due to these missing observations was observed. To retain those observations, we created a non-interpretable value for income that was named "missing". For the rest, three categories were used: below the 100% Federal Poverty Level (FPL), 100% or less than 200% of FPL, and all those at 200% FPL or above.

Predisposing factors are those characteristics that determine the likelihood of the need for health services based on the demographic, social structure, and health beliefs. The age variable was dichotomous for descriptive (table 5.2) and binary statistics (see table 5.3: age 20-45 years; age 46-64 years) because increasing age is concerned with increased periodontitis and we wanted to see the proportion of death in both higher age-category and moderate/severe periodontitis, while it was used as a continuous variable in multivariate analysis. The race variable was a categorical variable with White, Black, Mexican-American, and Other as the levels. Marital status was categorized as married, single/never married, and widowed/separated/divorced. Education category had three levels, "less than high school education", "high school education", and having "college degree or above". Family size had three levels as well as those having "1-2 individuals", family of "3-4 individuals", and "5 or more individuals". Rurality variable was dichotomous in nature that had "rural" and "urban" levels. Based on the USDA

classification codes, rurality was defined at the county level and served as a surrogate variable for dental health professional shortage area. Census Region variable was categorical with 4 levels; North-East, Midwest, South, and West based on Census classification of U.S. regions. Language of interview was dichotomous with those whose interview was conducted in "English" or "Spanish/Other language". This surrogate variable was meant to ascertain the ability of a person to communicate to the outside world.

Need characteristics were those that describe a person's need to obtain healthcare services, these could be actual or perceived needs. The Charlson co-morbidity index was used to determine the risk of death within ten years due to co-morbid conditions as proposed by Charlson et al. (1987). 1 point was given to each of the conditions like diabetes, asthma, cardio-vascular diseases, and stroke, while 6 points were given to those who had cancer disease. Based on the sum of the score for each person, this variable was divided into 4 categories; "Score of 0" for those who did not have any chronic disease, "Score of 1" for those who had only 1 listed chronic disease, "Score of 2" for those who had two or more listed chronic conditions, and "Score of 3 or more" for those who had 3 or more listed chronic conditions. "Self-described health status" and "Self-described dental health status" were dichotomous variables that were defined on the basis of Likert scale but compressed into two levels as: "Excellent/very good/good" and "Fair/Poor". Missing teeth was a dichotomous variable that was defined as "no missing tooth" and "any number of missing teeth" to adjust for periodontitis as periodontal disease is responsible for tooth loss (Löe, 1993).

Behavioral Factors

Behavioral factors were selected based on the literature review. Alcohol Use was a three level categorical variable with "Current Drinker" defined as the person who had at least 12 alcoholic beverages in the past one year at the time of survey, "Former Drinker" was defined as those who didn't have had any alcoholic beverage during the past one year but had at least 12 drinks in lifetime at the time of survey, and "Never Drinker" were those who never had any sort of alcoholic beverage in their lifetime at the time of survey. Heavy alcoholism had been found to be associated with increased risk of mortality especially in younger population (Klatsky et al., 1992; Marmot et al., 1981; Grønbæk et al., 2000; Di Castelnuovo A et al., 2006). Alcoholism had also been found to be a risk factor for periodontitis (Pitiphat et al., 2003; Tezal et al., 2001; Amaral et al., 2009; Lages et al., 2012). Tobacco Users were also categorized into three levels: "Current Tobacco User" were those who used tobacco product in the form of cigarette, pipe, cigar, snuff, or chewing tobacco at the time of survey. "Former Tobacco User" were those who smoked at least 100 cigarettes in life but did not smoke cigarettes, or did not smoke 20 cigars or 20 pipes of tobacco at the time of survey, or did not use tobacco in any other form (snuff and chewing tobacco) at the time of survey but have used all these products in lifetime at the time of survey, and "Never Tobacco User" were those who never smoked 100 cigarettes in life, and never smoked 20 cigars or 20 pipes of tobacco at the time of survey, and never used tobacco in any other form (snuff and chewing tobacco) at the time of survey at the time of survey. While numerous studies had linked the use of tobacco products to mortality (Gupta & Mehta, 2000; John & Hanke, 2003; John & Hanke, 2003), tobacco use had been linked as a strong risk factor with periodontitis as

well (Amarasena et al., 2002; Calsina et al., 2002; Rudzińiski, 2010; Ashril & Al-Sulamani, 2003; Johnson & Slach, 2001). Body Mass Index (BMI) was categorized into three levels based on the cut-off values as proposed by CDC (CDCb, 2015): Underweight and Normal BMI was placed together due to few number of observations in underweight, therefore, "Underweight/Normal Weight" were those who had a BMI of less than 25 kg/m^2 at the time of survey, "Overweight" those who fell in a BMI range of 25 to <30 kg/m^2, while "Obese" were defined as those who had a BMI of 30 kg/m^2 or more at the time of survey. Physical activity was a dichotomous variable that had a yes/no value based on whether a person performed any of the defined physical activities at the time of survey or not. Physical activities were defined as "walked or biked in the past 30 days, did any task around home/yard for at least 10 minutes during the past 30 days, did any moderate or vigorous activity over the past 30 days for at least 10 minutes, did any muscle strengthening over the past 30 days". Higher BMI and no physical activity level are risk factors for certain diseases like Diabetes and cardiovascular diseases, that have an effect on periodontitis, and at the same time, these are related to mortality (Merchant et al. 2003; Gocke et al. 2014; Prpić et al. 2012).

Statistical Analyses:

SAS v9.4 was used to perform all the statistical analyses. Proc survey procedures were used in SAS to reflect the complex sampling techniques of the survey adjusting for sampling weights, strata, and cluster variables to obtain national estimates for U.S. population. The cut-off p-value for all the analyses was at $\alpha = 0.05$. All analyses were separated for males and females. Descriptive statistics were obtained to observe the distribution of population characteristics among the samples. Binary statistics were

basically unadjusted mortality estimates for deceased persons. Chi-square based p-values were obtained to compare between deceased and alive groups of mortality. Cox-proportional hazard models were used to obtain the hazard ratios, which are the risk of mortality, with upper and lower confidence limits. An incremental set of models was developed to observe an incremental change in mortality risk. Model 1 was the simplified model to obtain mortality risk estimates for total periodontitis that was adjusted for age (as a continuous variable) and missing teeth only. In model 2, all enabling variables were added to model 1 to observe the change in mortality risk for total periodontitis. Model 3 was composed of simplified model, enabling, and pre-disposing variables. In model 4, need variables were added to model 3. And finally in model 5, confounding variables were added to model 4 to make it a full model.

Propensity Score Analysis:

This study used propensity scores to adjust for the differential distribution of dental coverage among various demographic metrics like race, education, marital status, total number of household, annual household income, and language of interview (see table 5.1) based on the concept proposed by Rosenbaum & Rubin (1983). Separate scores were calculated for both males and females to adjust for gender-separated multivariate cox proportional models. The purpose of propensity score was to measure the likelihood of having dental coverage with health insurance in the population. This score was obtained using predicted probabilities in a multinomial logistic regression model with the three-level insurance type as the dependent categorical variable and the demographic metrics described above as the confounding variables without the use of survey weights and strata variables. Only the propensity score for dental coverage with health insurance

was used in multivariate analyses because the purpose of the study was to the effect of dental coverage on periodontal mortality. The continuous probabilistic score that was obtained from propensity score analysis was converted into a 4 level categorical variable based on the quartile distribution of unweighted sample size. However, with the application of weights, and considering for strata and clustering, the proportion of sample within in each quartile did not remain equal due to difference in weights of the sample within each quartile (see table 5.2). This score was labeled as dental coverage propensity score and used as an enabling variable.

Results

Description of population

Approximately 9% of males and 6.57% of females had died due to various causes (see tables 5.2). Majority of the males had moderate/severe periodontitis (7.08%) as compared to 3.37% of the females. About 51% of both the male and female population had dental coverage with health insurance. About 37% of the male and 34% of the female population had the highest probability of having dental coverage with health insurance (fourth quartile) while about 11% of the male and 12% of the female population had the lowest probability of having dental coverage with health insurance. About 54% of the male and two-third of the female population made regular visits to dentists and dental hygienists. About 7 in 1 males, and about two-thirds of females lied at 200% or above the FPL. Majority of the population was in the age range of 20-45 years (about 78% of both males and females), non-Hispanic white (75% of the males and ~74% of the females), married (~69% males and 66% females), had a college degree or higher education (53% males and ~49% females), had 3-4 family members (43% among both males and

females), spoke English (93% males and 94% females), lived in Urban areas (53% males and ~50% females), and in the South (about one-third both males and females). There were about 39% among both males and females who had one or more missing teeth, about 85% of male and 80.47% of female population had no chronic disease, and majority of them rated their self-described general (~91% males and ~89% females) and dental health status (72.63% males and 73.25% females) as Excellent/Very Good/Good.

Risk Factors for Periodontitis

Table 5.3 describes the risk factors for periodontitis in the population studied.

Among males, there was no significant difference in the distribution of periodontitis among those having dental coverage with health insurance, dental visits, FPL, family size, rurality, Census region, and language of interview. The majority of the males who had moderate/severe periodontitis were in the older age-group of 46-64 years, non-Hispanic Black/Others (~11%), widowed/separated/married (13.68%), having less than a high school education, had a score of 3 or more on Charlson co-morbidity index (36.48%), had 1 or more missing teeth (14%), had fair/poor general (12.73%) and dental (12%) health, former consumer of alcohol (~11%), current user of tobacco products (11%), obese (~11%), and physically inactive (11.26%).

Among females, language of interview, rurality, and Census region did not have any statistical significance. About 2.5% were those who had dental coverage with health insurance. Majority of the females with moderate/severe periodontitis were uninsured (5.35%), had 5.35% of episodic visits, lied in the lowest quartile of the probability of dental coverage with health insurance (5.80%) and became progressively less with increasing quartile for the probability, living below 100% of FPL (5.45%), in the higher

age-group of 46-64 years (~9%), non-Hispanic Black (~7%), widowed / separated / divorced (5.20%), less than a high school education (8.82%), having a family size of 5 or more members (5.47%), had one or more missing teeth (6.28%), had a score of 3 or more on Charlson co-morbidity index (7.73%), and had a fair/poor self-rated general health (8.21%) and dental health status (7%).

Risk Factors for Mortality

The death rate was higher among men with moderate/severe periodontics (25.98%%) than among those with no/mild periodontitis (7.67%; see Table 5.4). Uninsured males had the fewest death rate (6.62%) followed by those males who had dental coverage with health insurance (7%). There was no significant difference on mortality among propensity quartiles for dental coverage with health insurance, FPL, and between dental visits. Males aged between 46-64 years had increased mortality rate (23.29%), of non-Hispanic Black origin (13.71%), widowed/separated/divorced (15%), had less than a high school (13.55%), 1-2 family members (11.69%), had a score of 3 or more on Charlson co-morbidity index (45.35%), one or more missing teeth (13.85%), self-rating of fair/poor on general and dental health status (22.82% & 13% respectively), current users of tobacco products (11%), were obese (15.88%), and had no physical activity (~17%).

Among females with periodontitis, the death rate was 22%. Death rate among females did not differ in different types of health insurance, propensity score for dental coverage with health insurance, dental visits, race, language of interview, rurality, region, and alcoholism. Females in the age-group of 46-64 years had the highest mortality rate (16.71%), those who were widowed/separated/divorced had a mortality rate of 10.67%,

similarly, less than a high school education (10.86%), having 1-2 family members (8.31%), had a score of 3 or more on Charlson co-morbidity index (19.69%), 1 or more missing teeth (~9%), and fair/poor self-rated general (15.28% and 8.44% respectively).

Adjusted Risk of Mortality among Males and Females

In simplified adjusted model, the risk of mortality was 1.96 times significantly higher among males who had moderate/severe periodontitis as compared to those who had no/mild periodontitis (data not shown in table 5.5). With the addition of dental insurance and propensity score for dental coverage variables in model 1, the risk of death was reduced to 1.88 among males due to moderate/severe periodontitis and dental coverage with health insurance had 0.69 times less the risk of death among males when compared to those males who had only health insurance. Those who had the lowest probability of having dental coverage (first quartile) were at higher risk of mortality (2.53) as compared to those who had the highest probability of dental coverage. When other enabling variables were added in model 2, the risk of mortality was reduced to 1.80 due to periodontitis and those who had dental coverage were protected from mortality (HR=0.70). Propensities for dental coverage became insignificant in this model. When pre-disposing characteristics were added in model 3, the mortality risk was reduced to 1.69 due to periodontitis while dental coverage was still protective significantly (HR=0.70). In model 4 when need variables were added, the mortality risk due to periodontitis was reduced to 1.45 but dental coverage became insignificant. After the addition of behavioral factors in model 5, mortality risk due to periodontitis and enabling variables were all insignificant.

Females had the highest risk of mortality (HR=2.01) due to periodontitis compared to males in simplified model (not shown in table 5.5). When dental coverage variable and propensity score variable were added in the model 1, the risk of mortality due to periodontitis was reduced to 1.70 and with the introduction of enabling variables in model 2, it was further reduced to 1.63, though the dental coverage or any of the enabling variables were insignificant. However, in model 3 when pre-disposing variables were added, the significant risk of mortality due to periodontitis was lost and remained insignificant till model 5, however, the third quartile of propensity score for dental coverage with health insurance became significant and remained significant till model 5. The third quartile of propensity score is the second-highest probability of having dental coverage with health insurance, and shows that when the difference for having dental coverage is reduced, females with a higher probability had a lower risk of death due to dental coverage.

Discussion

It is interesting to note that dental coverage had a significant protective effect till model 3 among males after which this effect became insignificant, however, no significant effect of dental coverage was seen among females in any of the models. As it could be seen in model 2 that males had a significantly higher risk of mortality in the first two quartiles of propensity score for dental coverage (50% of population distribution), which denote a lower probability of having dental coverage, this effect then became insignificant in the later models among males. However, among females, only the third quartile of propensity score for dental coverage (75^{th}% of the population distribution), a higher probability of having dental coverage, had a significant protective effect on the

risk of mortality from model 3 to model 5. This could mean that the removal of the bias (due to demographics and enabling characterisitics) to have dental coverage could save lives of females who had a higher probability of dental coverage as compared to those females who had the highest probability.

We have seen in our study that older age-group (46-64 years) had higher mortality and periodontitis was also higher in this age-group in both the genders. These finding were similar to Eke et al. (2012) where the prevalence of periodontitis increased with increasing age. Therefore, we could conclude that increased age is related to both mortality and moderate/severe periodontitis. In the study of Xu & Lu (2011) where only males aged 30-64 had a significant hazard ratio of 2.13 while there was no significant mortality risk observed in females due to periodontitis after adjusting for covariates, our study showed both males and females are at risk of mortality due to periodontitis even after controlling for all the enabling variables in model 2. However, from model 3 to 4 among males, the risk of mortality was still significantly higher and became insignificant after the controlling for behavioral factors in models 5.

One of the several reasons for insignificant risk of mortality due to periodontitis could be the following. Females, in general, have a tendency for losing bone mineral density with age, especially in post menopause, that reduces the alveolar bone (supporting bone that is responsible for clinical attachment loss) causing loss of attachment and thus being positive on having periodontitis (Tezal et al., 2000; Payne et al., 1997), however, this periodontitis is not related to periodontitis caused by pathogens. This could explain the insignificant risk of periodontitis among females after adjusting

for predisposing, need, and behavioral factors. There is a need to differentiate between pathogenic periodontitis from hormone-induced periodontitis among females.

The presence of unhealthy behavioral factors in both males and females like tobacco use and physical inactivity delineate a higher risk factor for other systemic diseases like cancer and diabetes, and contribute to mortality. Gupta et al., (2005) showed in their study that various types of tobacco products have varying but higher risk of mortality and John & Hanke, (2003) have showed that tobacco-related mortality affects latter age-groups than younger. Similarly, according to Kujala UM et al., (1998) leisure-time physical activity is related to reduced mortality even after controlling for genetic and familial factors. Another study by Paffenbarger et al., (1986) showed that the lack of physical activity was related to higher mortality irrespective of the other systemic and behavioral factors in the Harvard alumni. All these studies contribute to the fact that mortality in older working age-group is related to bad behavioral factors and those who actively use tobacco products and did not remain physically active had the higher risk of death due to these factors and not periodontitis. According to a meta-analysis by Garcia et al., (2001), systemic diseases had its effects on periodontal health and periodontal diseases had its effects on systemic diseases. Though the risk of mortality was lowered (but significant) for periodontal diseases in the presence of chronic diseases in model 4 for males as compared to model 3, we also saw a higher risk of mortality due to chronic diseases than periodontal diseases itself among both the genders, this could indicate that both periodontal and chronic systemic diseases aggravate each other and the risk of mortality could be a cumulative effect of both or perhaps, for competing risk factors, health insurance is needed more. Among both the genders, the active use of tobacco

products along with chronic diseases and fair/poor self-rated health status, all had a higher risk of mortality but had no effect on the risk of mortality due to periodontitis in the final model. It is evident that the use of tobacco products leads to higher mortality. Tobacco use could lead to oral or lung cancers depending on the use, affecting periodontal health simultaneously (Agnihotri et al. 2014). Similarly, being physically inactive has a higher risk of mortality. People who exercise, and remain physically active have less general and oral health problems (Merchant et al. 2003). Therefore, the higher risk of death could be due to the unhealthy life style. Ekuni et al. (2008) and Suvan et al. (2011) reported a positive association between BMI and periodontitis, in this study, we have seen that controlling for BMI takes the significance away from mortality risk due to periodontitis.

Conclusion

Periodontitis is a preventable disease if diagnosed in time. Early detection that starts with inflammation of the gums which could be detected and treated through mechanical cleaning of teeth by a dentist or dental hygienist. But regular visit to a dentist or dental hygienist is guaranteed by dental coverage (Bloom & Cohen, 2010; Teusner et al., 2014; Brennan et al., 2013; Manski et al., 2004; Anikeeva et al. 2013). Though dental coverage among males was insignificant in the final model, however, in our study we did not have knowledge about the depth of coverage and co-payments associated with dental coverage that could potentially influence the uptake of dental services by the individuals (Freeman et al. 2008). However, according to Newman & Gift, (1992) provision of regular preventive services were dependent upon having dental coverage with no financial barrier among others. We could also see from RAND health insurance

experiment that the overall oral health of the individuals improved in those who had less cost barrier to dental services (Brook et al. 2006; Bailit et al. 1985). Research shows that periodontitis is strongly associated with other systemic diseases like cardiovascular diseases, diabetes, and stroke (Li et al., 2000; Meurman et al., 2004; Jansson et al., 2002; Jansson et al., 2001; Awano et al., 2008; Weidlich et al., 2008; Debelian et al., 1994). Therefore, we suggest that provision of preventive dental services with no cost barrier should be mandated in health reforms for adults, under Medicaid expansion and healthcare.gov, to improve the overall general and dental health of adults.

Limitations

This was a cross-sectional study and the results do not prove causality. For this study, we used NHANES III data that made use of PMPE, therefore, there is a random misclassification bias associated with the measurement of periodontitis that led to the underestimation of the prevalence of periodontitis, and thus the associated mortality risk. It is recommended that NHANES 2009-2010 should be used for the measures of periodontal associations with mortality due to the use of FMPE (gold standard), however, there is a need for sufficient cases of mortality to be accumulated over the years to conduct a viable mortality analysis in that dataset. Furthermore, the mortality cases included the violent and accidental causes of death in this study and these could not be eliminated due to lack of funding to gain access to restricted dataset. However, Kim et al. (2013) found that there were about 6% of such cases in mortality dataset related to NHANES 1999-2004, and we assume that these have not cause a deviation in the measures of association.

Table 5. 1 Proportion of respondents with dental coverage, Working Age Adults, 1988-1994 NHANES, by respondent characteristics

N= 8746	For Age between 20 & 64 Years			
	Percent of Males with Dental Coverage (N=3990)		Percent of Females with Dental Coverage (N =4756)	
Variables	**%**	**SE**	**%**	**SE**
Pre-disposing Characteristics				
Race*				
Non-Hispanic White	54.02	2.21	54.51	1.9
Non-Hispanic Black	51.33	2.4	51.11	2.16
Mexican-American	33.03	1.41	32.23	1.73
Others	35.11	4.89	36.57	5.67
Marital*				
Married	56.22	2	54.63	1.73
Widowed/Separated/Divorced	37.51	4.91	40.5	3.07
Never Married	39.12	2.66	49.02	2.47
Education*				
Less than High School	28.55	2.49	27.45	2.55
High School	48.76	2.43	49.89	2.25
College Degree or More	58.69	2.27	59.41	2.2
Federal Poverty Level*				
Less than 100% FPL	17.6	2.73	20.95	2.99
100% to less than 200% FPL	29.34	3.31	34.7	2.39
More than 200% FPL	60.75	2.05	61.85	1.99
Missing	34.21	6.06	35.66	5.62
Family size†				
1-2 Family Members	49.3	2.69	53.93	2.45
3-4 Family Members	55.08	2.39	51.72	2.18
5 or more family members	43.74	3.22	44.48	2.66
Enabling Factors				
Dental Visits*				
Regular	61.02	2.1	60.65	1.78
Episodic	38.6	2.16	32.28	1.83
Language of Interview*				
English	53.01	1.89	53.54	1.52
Spanish/Other	19.69	3.27	16.1	3.88

Rurality*				
Urban	55.46	2.1	54.78	2.12
Rural	45.76	2.62	48.08	2.53
Regionᵠ				
North-East	55.46	5.39	54.25	3.64
Mid-West	51.08	3.16	51.77	2.51
South	48.55	2.61	47.6	2.28
West	50.17	3.91	54.35	2.9

**Both Male & Female significant at p <.05*

† *Only Male significant at p <.05*

ᵠ *Only Female significant at p <.05*

Table 5. 2Population Characteristics among Working Age Adults: NHANES 1988-1994 (weighted)

N= 8746	Males (N=3990)		Females (N=4756)	
Variables	**%**	**SE**	**%**	**SE**
Dependent Variable				
Mortality				
Deceased	8.97	0.6	6.57	0.59
Independent Variable				
Periodontitis Categories				
No / Mild Periodontitis	92.92	0.59	96.63	0.43
Moderate/Severe Periodontitis	7.08	0.59	3.37	0.43
Enabling Factors				
Dental Coverage				
Uninsured	15.33	1.14	12.32	1.02
Dental Coverage with Health Insurance	50.88	1.75	51.42	1.49
Only Health Insurance	33.8	1.81	36.26	1.32
Propensity Quartiles for Dental Coverage				
First Quartile (Lowest Probability of Dental Coverage)	10.86	0.84	12.16	1.06
Second Quartile	22.19	1.24	20.53	1.01
Third Quartile	30.09	1.45	33.27	1.25
Fourth Quartile (Highest Probability of Dental Coverage)	36.85	1.54	34.04	1.24
Dental Visits				
Regular	53.83	1.5	66.3	1.41
Episodic	46.17	1.5	33.7	1.41
Federal Poverty Level				
Less than 100% FPL	8.93	0.79	11.51	1.01
100% to less than 200% FPL	16.5	1.01	17.34	0.97
More than 200% FPL	69.56	1.26	65.75	1.33
Missing	5	0.53	5.4	0.45
Pre-disposing Characteristics				
Age				
20-45 Years	78.02	1.1	77.77	0.98
46-64 Years	21.98	1.1	22.23	0.98
Race				
Non-Hispanic White	75.39	1.42	74.31	1.34
Non-Hispanic Black	9.42	0.58	11.54	0.84
Mexican-American	6.76	0.66	5.67	0.49

Others	8.43	1.08	8.47	0.89
Marital				
Married	68.84	1.29	66.32	1.41
Widowed/Separated/Divorced	7.3	0.56	15.68	0.99
Never Married	23.86	1.35	18	1.12
Education				
Less than High School	16.66	1.08	15.32	1.06
High School	30.22	1.18	35.86	1.19
College Degree or More	53.12	1.74	48.82	1.43
Family size				
1-2 Family Members	39.33	1.74	40.11	1.33
3-4 Family Members	43.43	1.39	43.06	1.18
5 or more family members	17.24	0.92	16.84	0.7
Language of Interview				
English	93.31	0.87	94	0.78
Spanish/Other	6.69	0.87	6	0.78
Rurality				
Urban	53.19	4.79	50.01	4.86
Rural	46.81	4.79	49.99	4.86
Region				
North-East	19.73	1.36	20.33	1.43
Mid-West	24.32	1.5	22.28	1.54
South	33.85	2.92	34.46	3.05
West	22.1	3.58	22.93	4
Need Variables				
Charlson Co-morbidity Index				
Score of 0	85.07	0.86	80.47	0.82
Score of 1	9.95	0.68	11.03	0.7
Score of 2	3.46	0.47	6.95	0.5
Score of 3 or more	1.52	0.26	1.55	0.24
Missing Teeth				
Yes	38.71	1.36	39.26	1.27
Self-Rated Health Status				
Excellent/Very Good/Good	91.38	0.69	88.83	0.64
Fair/Poor	8.62	0.69	11.17	0.64
Self-Rated Dental Health Status				
Excellent/Very Good/Good	72.63	1.31	73.25	1.12
Fair/Poor	27.37	1.31	26.75	1.12

Behavioral Factors				
Alcohol				
Current Drinker	73.42	1.39	51.64	1.53
Former Drinker	21.14	1.27	32.1	1.13
Never Drinker	5.43	0.53	16.27	0.98
Tobacco Use in any Form				
Current User of Tobacco Products	35.8	1.04	25.18	1.04
Former User of Tobacco Products	28.9	1.21	18.34	0.9
Never Used Tobacco Products	35.29	1.21	56.48	1.29
BMI				
Normal Weight/Underweight	42.58	1.22	53.74	1.33
Overweight	39.47	1.29	24.2	0.82
Obese	17.95	0.85	22.07	1.13
Physical activity				
No	8.08	0.81	13.76	0.93

Table 5. 3 Rate of Periodontitis, Working Age Adults, 1988-1994 NHANES

	Male (N=3990)			Female (N = 4756)		
Variables	**%**	**SE**	**p-value**	**%**	**SE**	**p-value**
Enabling Factors						
Dental Coverage			0.3539			0.0168
Uninsured	5.35	0.95		5.35	1.17	
Dental Coverage with Health Insurance	7.01	0.96		2.50	0.51	
Only Health Insurance	7.78	0.99		3.66	0.59	
Dental Visits			0.6973			<.0001
Regular	6.87	0.83		2.36	0.44	
Episodic	7.33	0.85		5.35	0.80	
Propensity Quartiles			0.2294			0.0137
First	6.43	1.30		5.80	1.28	
Second	7.14	1.09		3.88	0.86	
Third	8.65	1.42		3.17	0.60	
Fourth	5.86	0.83		2.44	0.48	
Federal Poverty Level			0.3221			0.0031
Less than 100% FPL	9.88	1.56		5.45	1.50	
100% to less than 200% FPL	7.55	1.27		4.79	0.90	
More than 200% FPL	6.64	0.82		2.54	0.37	
Missing	6.74	1.92		4.45	1.52	
Pre-disposing Characteristics						
Age			<.0001			<.0001
20-45 Years	4.02	0.60		1.75	0.31	
46-64 Years	17.94	1.74		9.06	1.28	
Race			<.0001			0.0015
Non-Hispanic White	6.14	0.71		2.86	0.54	
Non-Hispanic Black	11.37	0.89		6.99	0.89	
Mexican-American	6.68	0.94		3.25	0.33	
Others	11.09	1.85		3.00	1.51	
Marital			<.0001			<.0001
Married	7.90	0.75		3.55	0.49	
Widowed/Separated/Divorced	13.68	3.63		5.20	1.16	
Never Married	2.69	0.71		1.14	0.26	
Education			<.0001			<.0001
Less than High School	12.95	1.61		8.82	1.94	
High School	8.24	0.86		2.96	0.65	
College Degree or More	4.53	0.66		2.00	0.36	

Family size			0.4347			0.0228
1-2 Family Members	7.90	1.09		3.66	0.71	
3-4 Family Members	6.29	0.76		2.28	0.41	
5 or more family members	7.22	1.31		5.47	1.48	
Need Variables						
Charlson Co-morbidity Index			<.0001			0.0017
Score of 0	6.01	0.65		2.86	0.42	
Score of 1	9.15	1.91		4.88	1.23	
Score of 2	14.63	4.51		5.94	1.41	
Score of 3 or more	36.48	10.16		7.73	2.95	
Missing Teeth			<.0001			<.0001
No	2.65	0.48		1.50	0.37	
Yes	14.05	1.18		6.28	0.82	
Self-Rated Health Status			0.0083			<.0001
Excellent/Very Good/Good	6.55	0.64		2.76	0.37	
Fair/Poor	12.73	2.69		8.21	1.69	
Self-Rated Dental Health Status			<.0001			<.0001
Excellent/Very Good/Good	5.19	0.64		2.02	0.33	
Fair/Poor	12.07	1.26		7.06	1.22	
Behavioral Factors						
Tobacco Use in any Form			<.0001			<.0001
Current User of Tobacco Products	11.00	1.35		5.74	0.96	
Former User of Tobacco Products	7.57	1.23		4.34	1.03	
Never Used Tobacco Products	2.72	0.65		2.00	0.27	
BMI			0.0005			0.0001
Normal Weight/Underweight	5.25	0.71		2.10	0.43	
Overweight	7.34	0.92		4.31	0.73	
Obese	10.85	1.44		5.43	1.01	
Physical activity			0.0409			0.0008
Yes	6.72	0.59		2.90	0.46	
No	11.26	2.68		6.33	1.13	

Table 5. 4 Proportion Deceased by 2011 among Working Age Adults, by respondent characteristics, 1988-1994 NHANES

	Male (N=3990)			Female (N = 4756)		
Variables	**%**	**SE**	**p-value**	**%**	**SE**	**p-value**
Overall mortality	8.97	0.60		6.57	0.59	
Independent Variable						
Periodontitis Categories			<.0001			0.00
No / Mild Periodontitis	7.67	0.60		6.02	0.53	
Moderate/Severe Periodontitis	25.98	2.69		22.23	4.20	
Enabling Factors						
Dental Coverage			<.0001			0.06
Uninsured	6.62	1.19		7.61	1.43	
Dental Coverage with Health Insurance	7.09	0.77		5.23	0.62	
Only Health Insurance	12.29	1.21		7.43	1.03	
Dental Visits			0.93			0.68
Regular	8.94	0.87		6.41	0.76	
Episodic	9.03	0.66		6.86	0.81	
Propensity Quartiles			0.50			0.08
First	10.89	1.69		8.78	1.20	
Second	8.85	1.12		8.07	1.20	
Third	9.17	1.24		5.55	0.92	
Fourth	8.14	0.71		5.89	0.96	
Federal Poverty Level			0.05			0.00
Less than 100% FPL	12.78	2.00		6.32	1.11	
100% to less than 200% FPL	10.15	1.26		7.89	1.24	
More than 200% FPL	8.23	0.71		5.64	0.69	
Missing	8.53	2.01		14.23	3.26	
Pre-disposing Characteristics						
Age		<.0001				<.0001
20-45 Years	4.92	0.57		3.66	0.53	
46-64 Years	23.29	1.69		16.71	1.30	
Race			0.02			0.19
Non-Hispanic White	8.69	0.83		6.57	0.72	
Non-Hispanic Black	13.71	1.18		8.30	0.65	
Mexican-American	8.54	0.96		5.22	0.64	
Others	6.54	2.05		5.07	1.66	
Marital			<.0001			0.00
Married	9.78	0.70		6.18	0.76	

Widowed/Separated/Divorced	14.95	2.28		10.67	1.24	
Never Married	4.80	0.89		4.33	1.13	
Education			<.0001			0.00
Less than High School	13.55	1.58		10.86	1.68	
High School	9.95	0.86		6.93	0.81	
College Degree or More	6.85	0.74		4.99	0.73	
Family size			0.01			0.02
1-2 Family Members	11.69	1.19		8.31	0.87	
3-4 Family Members	6.92	0.96		5.26	0.77	
5 or more family members	7.91	1.32		5.73	1.26	
Language of Interview			0.80			0.11
English	9.00	0.64		6.71	0.61	
Spanish/Other	8.50	1.77		4.36	1.15	
Rurality			0.74			0.49
Urban	8.76	0.64		6.18	0.85	
Rural	9.20	1.12		6.95	0.75	
Region			0.36			0.29
North-East	9.53	1.30		6.67	1.62	
Mid-West	9.43	1.25		7.07	0.56	
South	9.58	1.13		7.45	1.11	
West	6.99	1.05		4.65	0.98	
Need Variables						
Charlson Co-morbidity Index			<.0001			<.0001
Score of 0	7.02	0.57		5.22	0.54	
Score of 1	15.28	2.26		10.82	1.67	
Score of 2	22.59	4.95		12.47	2.82	
Score of 3 or more	45.35	9.13		19.69	5.43	
Missing Teeth			<.0001			<.0001
No	5.85	0.66		4.96	0.72	
Yes	13.85	1.14		9.07	0.87	
Self-Rated Health Status			<.0001			<.0001
Excellent/Very Good/Good	7.66	0.62		5.47	0.62	
Fair/Poor	22.82	2.59		15.28	2.42	
Self-Rated Dental Health Status			<.0001			0.03
Excellent/Very Good/Good	7.42	0.65		5.88	0.67	
Fair/Poor	13.02	1.24		8.44	1.11	
Behavioral Factors						
Alcohol			0.17			0.35

Current Drinker	8.29	0.82		6.08	0.90	
Former Drinker	11.20	1.46		7.74	1.01	
Never Drinker	9.26	2.27		6.16	0.99	
Tobacco Use in any Form			0.00			<.0001
Current User of Tobacco Products	11.16	1.09		10.71	1.12	
Former User of Tobacco Products	10.47	1.30		6.41	1.27	
Never Used Tobacco Products	5.52	0.75		4.77	0.50	
BMI			<.0001			<.0001
Normal Weight/Underweight	7.75	0.71		4.38	0.65	
Overweight	7.17	0.98		8.43	1.14	
Obese	15.88	1.98		9.86	1.51	
Physical activity			<.0001			0.01
Yes	8.27	0.61		6.16	0.60	
No	16.94	2.46		9.11	1.27	

Table 5. 5 Dental coverage mitigated adjusted risk of mortality due to periodontitis among working age-group of males

	Model 1	Model 2	Model 3	Model 4	Model 5
	Male	Male	Male	Male	Male
Variables	**HR**	**HR**	**HR**	**HR**	**HR**
Independent Variable					
Age	1.08	1.09	1.08	1.08	1.08
Periodontitis Categories					
No / Mild Periodontitis	Referent Variable	Referent Variable	Referent Variable	Referent Variable	Referent Variable
Moderate/Severe Periodontitis	1.88*	1.8*	1.69*	1.45*	1.14
Enabling Factors					
Dental Coverage					
Only Health Insurance	Referent Variable	Referent Variable	Referent Variable	Referent Variable	Referent Variable
Dental Coverage with Health Insurance	0.69*	0.72*	0.7*	0.73	0.79
Uninsured	0.8	0.71	0.71	0.75	0.77
Propensity Score for Dental Coverage					
Fourth Quartile	Referent Variable	Referent Variable	Referent Variable	Referent Variable	Referent Variable
First Quartile	2.53*	1.59	1.27	0.97	1.18
Second Quartile	1.45*	1.17	0.84	0.72	0.75
Third Quartile	1.05	1.05	0.84	0.83	0.83
Dental Visits					
Regular		Referent Variable	Referent Variable	Referent Variable	Referent Variable
Episodic		1.3	1.21	1.23	1.05
Federal Poverty Level					
More than 200% FPL		Referent Variable	Referent Variable	Referent Variable	Referent Variable
100% to less than 200% FPL		1.28	1.39	1.25	1.3

Less than 100% FPL		1.91	2.03	2.01	2.13
Missing		0.69	0.83	0.96	1.06
Pre-disposing Characteristics					
Race					
Non-Hispanic White			Referent Variable	Referent Variable	Referent Variable
Non-Hispanic Black			1.73*	1.67*	1.63*
Mexican-American			1.32	1.34	1.29
Others			0.78	0.71	0.63
Marital					
Never Married			Referent Variable	Referent Variable	Referent Variable
Married			0.88	0.81	0.82
Widowed/Separated/Divorced			0.84	0.85	0.81
Education					
College Degree or More			Referent Variable	Referent Variable	Referent Variable
High School			1.49*	1.37	1.31
Less than High School			1.4	1.16	0.92
Family size					
1-2 Family Members			Referent Variable	Referent Variable	Referent Variable
3-4 Family Members			0.67	0.7	0.75
5 or more family members			0.69	0.65	0.62
Language of Interview					
English			Referent Variable	Referent Variable	Referent Variable
Spanish/Other			0.74	0.86	0.93
Rurality					
Urban			Referent Variable	Referent Variable	Referent Variable
Rural			0.99	0.96	1.01

Region					
North-East			Referent Variable	Referent Variable	Referent Variable
Mid-West			0.86	0.8	0.8
South			0.93	0.86	0.81
West			0.72	0.62	0.6
Need Variables					
Charlson Co-morbidity Index					
Score of 0				Referent Variable	Referent Variable
Score of 1				1.78*	1.76*
Score of 2				1.39	1.33
Score of 3 or more				2.77*	2.38*
Missing Teeth					
No					Referent Variable
Yes					1.4
Self-Rated Health Status					
Excellent/Very Good/Good				Referent Variable	Referent Variable
Fair/Poor				2.02*	1.88*
Self-Rated Dental Health Status					
Excellent/Very Good/Good				Referent Variable	Referent Variable
Fair/Poor				1.18	1.2
Behavioral Factors					
Alcohol					
Never Drinker					Referent Variable
Current Drinker					0.87
Former Drinker					0.71
Tobacco Use in any Form					

Never Used Tobacco Products					Referent Variable
Current User of Tobacco Products					1.67*
Former User of Tobacco Products					1.02
BMI					
Normal Weight/Underweight					Referent Variable
Obese					1.24
Overweight					0.69*
Physical activity					
No					1.64*

* = significant at α 0.05

Table 5. 6 Dental Coverage Mitigated Adjusted Risk of Mortality due to Periodontitis Among Working age-group of Females

	Model 1	Model 2	Model 3	Model 4	Model 5
	Male	Male	Male	Male	Male
Variables	**HR**	**HR**	**HR**	**HR**	**HR**
Independent Variable					
Age	1.07	1.08	1.08	1.08	1.09
Missing Teeth					
No	Referent Variable	Referent Variable	Referent Variable	Referent Variable	Referent Variable
Yes	1.17	1.16	1.12	1.05	1.07
Periodontitis Categories					
No / Mild Periodontitis	Referent Variable	Referent Variable	Referent Variable	Referent Variable	Referent Variable
Moderate/Severe Periodontitis	1.94*	1.6	1.45	1.24	1
Enabling Factors					
Dental Coverage					
Only Health Insurance		Referent Variable	Referent Variable	Referent Variable	Referent Variable
Dental Coverage with Health Insurance		0.93	0.97	0.93	0.91
Uninsured		1.15	1.27	1.23	1.13
Propensity Score for Dental Coverage					
Fourth Quartile		Referent Variable	Referent Variable	Referent Variable	Referent Variable
First Quartile		0.86	0.35	0.36	0.33
Second Quartile		0.72	0.3	0.28	0.26
Third Quartile		0.7	0.42	0.42	0.41

Dental Visits					
Regular		Referent Variable	Referent Variable	Referent Variable	Referent Variable
Episodic		1.15	1.14	1.1	1.01
Federal Poverty Level					
More than 200% FPL		Referent Variable	Referent Variable	Referent Variable	Referent Variable
100% to less than 200% FPL		1.95	2.85	2.83	3.14
Less than 100% FPL		1.61	2.58	2.23	2.33
Missing		2.5	4.19	3.95	4.12
Pre-disposing Characteristics					
Race					
Non-Hispanic White			Referent Variable	Referent Variable	Referent Variable
Non-Hispanic Black			0.9	0.84	0.73
Mexican-American			1.04	0.94	0.94
Others			0.91	0.92	1.16
Marital					
Never Married			Referent Variable	Referent Variable	Referent Variable
Married			0.62	0.61	0.51
Widowed/Separated/Divorced			0.79	0.76	0.6
Education					
College Degree or More			Referent Variable	Referent Variable	Referent Variable
High School			1.61	1.58	1.54
Less than High School			1.61	1.55	1.58

Family size					
1-2 Family Members			Referent Variable	Referent Variable	Referent Variable
3-4 Family Members			0.87	0.86	0.9
5 or more family members			1.07	1.08	1.15
Language of Interview					
English			Referent Variable	Referent Variable	Referent Variable
Spanish/Other			0.37	0.3	0.31
Rurality					
Urban			Referent Variable	Referent Variable	Referent Variable
Rural			1.13	1.08	1.1
Region					
North-East			Referent Variable	Referent Variable	Referent Variable
Mid-West			1.01	1	0.94
South			1.32	1.29	1.42
West			0.86	0.85	0.86
Need Variables					
Charlson Co-morbidity Index					
Score of 0				Referent Variable	Referent Variable
Score of 1				2.13	1.98
Score of 2				1.53	1.3
Score of 3 or more				1.81	1.54
Self-Rated Health Status					

Excellent/Very Good/Good				Referent Variable	Referent Variable
Fair/Poor				1.85	1.82
Self-Rated Dental Health Status					
Excellent/Very Good/Good				Referent Variable	Referent Variable
Fair/Poor				1.06	0.97
Confounding Factors					
Alcohol					
Never Drinker					Referent Variable
Current Drinker					1.45
Former Drinker					1.2
Tobacco Use in any Form					
Never Used Tobacco Products					Referent Variable
Current User of Tobacco Products					2.32
Former User of Tobacco Products					0.98
BMI					
Normal Weight/Underweight					Referent Variable
Obese					1.74
Overweight					1.46
Physical activity					
No					1.04

*= significant at α 0.05

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