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Dental caries and diabetes in the elderly population in San Juan, Puerto Rico

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CERTIFICATION

We hereby certify that the research project titled *"Dental caries and diabetes in the elderly population in San Juan, Puerto Rico"*, a requirement for the Master of Science in Epidemiology, completed by Katherine Svensson and presented in this document, fulfills the criteria of the Department of Biostatistics and Epidemiology of the Graduate School of Public Health, Medical Sciences Campus, University of Puerto Rico.

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ABSTRACT

People 65 years or older constitute 11.2% of the population in Puerto Rico, where the prevalence of diabetes is 31.9%. It has been hypothesized that diabetes could be a risk factor for caries due to increased glucose in saliva, decreased salivary flow and frequent intervals of food ingestion. This cross-sectional study compared the caries distribution among non-institutionalized adults aged 70 years and older, with and without diabetes. Participants were selected from a large representative sample of the Puerto Rican Elderly Health Conditions Study. Our study group included 184 individuals who underwent a comprehensive oral exam where decayed, missing, and filled surfaces, root caries and root restorations were assessed. Linear regression was used to analyze the caries outcome of DMFS, while DS and FS were assessed by a Poisson regression model. The outcome of MS was dichotomized by the median ($\leq$50 and >50 surfaces) and analyzed by a logistic regression model. When comparing mean DMFS index, participants with diabetes had significantly less filled surfaces (10.5 vs. 17.0; $p<0.05$) than those without diabetes. Due to interaction effects in the Poisson multivariate models to explain the decayed and filled surfaces, the analysis was stratified in subgroups. Among male participants, diabetes was significantly associated with decayed surfaces among smokers (RD = 2.23, 95% CI: 1.09, 4.56) and among non-smokers (RD = 4.43, 95% CI: 2.08, 9.40); however, these differences were not significant among women. Participants with diabetes had less filled surfaces in both age groups (<78 years: RD = 0.84; 95% CI: 0.53, 1.33; $\geq$78 years: RD = 0.55; 95% CI: 0.29, 1.04) when compared to those without diabetes. A non-significantly higher odds of having more missing surfaces was found among participants with diabetes (OR = 1.51; 95% CI: 0.76, 2.99). No differences were found in root caries and root restorations across diabetes status ($p>0.05$). Further prospective studies are warranted to confirm the higher number of decayed and missing surfaces among elderly people with diabetes.

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DEDICATION

This work is dedicated to all people living with diabetes, who struggle with this disease every day. I hope that the work of my thesis is only the beginning of many other investigations, and that someday it may be reflected in improved quality of life for these patients.

"Life is not merely to be alive, but to be well."

Marcus Valerius Martial

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CHAPTER 1: INTRODUCTION

1.1. Introduction

The proportion of older people is growing faster than any other age group. Approximately 600 million people are aged 60 years and over, and this number will double by 2025. It is expected that by 2050 this population will be 2 billion, and 80% will be living in developing countries (Petersen and Yamamoto, 2005). Many chronic diseases like cardiovascular disease, hypertension, cancer and diabetes are prevalent in the elderly population; therefore, the importance of monitoring this population to minimize the risks and improve their life quality is underscored (Petersen and Yamamoto, 2005). As this age cohort is increasing, so will the burden of health care system and the demand for access to health care services (Greene, 2005).

The oral health has been related with the general health status because of common risk factors, and associations have been found with diabetes mellitus, cardiovascular disease and chronic respiratory disease. Among elderly people, poor health is seen in a high level of tooth loss, dental caries experience, periodontal disease, xerostomia and oral cancer (Petersen and Yamamoto, 2005). The caries index has in general been decreasing in the last decades but is still a problem in the elderly people (Beltrán-Aguilar et al., 2005). As the population ages more root surfaces become exposed and are at increased risk for tooth decay (Beltrán-Aguilar et al., 2005). Furthermore, the percent of edentulous is decreasing, and more teeth are retained in older age, increasing the number of surfaces at risk for caries development (Saunders and Meyerowitz, 2005). Thus, it is important to develop strategies for preventing and controlling dental caries in older adults (Beltrán-Aguilar et al., 2005). The caries progression in older people is similar to that in younger people; however, elderly have more risk factors (Saunders and Meyerowitz, 2005). According to various studies, diabetes can be a risk factor for caries due to increased glucose in saliva, increased glucose in gingival cervical fluid, decreased salivary flow and more frequent intervals of food ingestion (Hintao et al., 2007; Cherry-Peppers & Skip, 1993; Taylor et al., 2004).

In Puerto Rico, the older population constitutes an 11.2% of the entire population (Census 2000), and the prevalence of diabetes in this age group is 31.9% (95% CI: 29.2%, 34.5%) (BRFSS, 2009). Studies focused on the oral health of the elderly population in Puerto Rico are scarce. This study evaluated for the first time the association between caries and diabetes in the elderly population living in San Juan, Puerto Rico.

1.2. Magnitude of the problem

1.2.1. Caries trends

Dental caries is a common chronic disease that causes pain and disability across all age groups (Beltrán-Aguilar et al., 2005). It is clinically defined as a lesion that extends beyond the surface of enamel of cementum and is identified by being penetrable with the dental explorer and by discoloration ranging from white to deep brown (Saunders and Meyerowitz, 2005). It is a progressive infection that starts with demineralization of enamel or cementum by organic acids produced by oral bacteria in plaque (Saunders and Meyerowitz, 2005). The incidence of coronal and root caries is greater in older adults than in adolescents, which means that elderly people are a caries-active group experiencing new disease at a rate at least as great as that of adolescents (Thomson, 2004). Root caries increases with age, with the highest prevalence in age group 65 years and older (Beltrán-Aguilar et al., 2005). It has been observed that root caries is more common among older people and approximately 14.5% of persons 65 years and older has at least one surface with decayed root caries (Dye et al., 2007).

The dental caries will be a significant problem for both community and institutionalized elderly adults in the foreseeable future, thus improvement in prevention strategies based on the multiple risk factors is needed (Saunders and Meyerowitz, 2005). Elderly adults and smokers are worse off than their counterparts, and these population subgroups are probably at increased risk for adverse consequences of tooth loss and other dental problems on quality of life and general health. These consequences include limitations in chewing, dissatisfaction with appearance, avoidance of social contacts and trouble speaking (Beltrán-Aguilar et al., 2005). The available data worldwide show that dental caries is a major public health problem in older people and closely linked to social and behavioral factors. Those who have low income, infrequent dental evaluation and high consumption of sugars and smoking tend to have a higher incidence of coronal and root caries (Petersen and Yamamoto, 2005).

Among the Hispanic population in the United States of America (USA), Puerto Ricans exhibit higher levels of gingivitis, periodontal diseases and high caries level. Cubans and Puerto Ricans have twice as many teeth as Mexican-Americans (Ismail and Szpunar, 1990). In general, Hispanics visit the dentist less and has twice as many decayed teeth than non-Hispanic. Furthermore, elderly adults in the minority groups have more decayed teeth than non-Hispanic elderly adults (Watson and Brown, 1995; Greene, 2005). To date, there is very scarce data on the oral health status of the elderly population in Puerto Rico. In the year 1990, an oral health assessment was conducted in the municipality of Culebra, Puerto Rico. According to this study, the caries index among adults 65 years and older in this municipality was higher than the index reported in the US by the NHANES (1994) for the same age-group (DMFT=23.0 vs. DMFT=18.5, respectively) (A. Elías-Boneta, unpublished data). Another pilot study in San Juan, Puerto Rico, conducted during the year 2000, evaluated the oral health status of adults 60 years old and over; 147 living in 20 independent retiring housing, and 145 that were non-institutionalized. The result showed a higher caries index (institutionalized: DMFS = 82.8 and non-institutionalized: DMFS = 73.5) (A. Elías-Boneta, unpublished data), compared to what is reported in the US (DMFS = 69.9) for the same age group (Dye et al., 2007).

1.2.2. Diabetes mellitus trends

According to the National Health and Nutritional Examination Survey (NHANES) during the years 1999-2002, the prevalence of diabetes in the USA was 9.3% (6.5 % diagnosed and 2.8% undiagnosed). This prevalence increases with age reaching 21.6% (15.8% diagnosed and 5.8% undiagnosed) in adults 65 years and older (Cowie et al., 2006). Compared with other ethnic groups in the USA, Puerto Ricans and Mexican Americans have the highest rate of diabetes compared with Cubans and non-Hispanics. Mexicans and Puerto Ricans in the USA have almost twice the rate of diabetes than Whites with 13.4% and 6.2%, respectively. In the population aged 65-74 years, diabetes is present in one-third of the Hispanic population (Harris, 2001).

The overall prevalence of diabetes in Puerto Rico has been fluctuating between 10.8% in 1996 to 8.6% in 2000 (Pérez-Perdomo et al., 2004) and 12.9% in 2009 (BRFSS, 2009). It increases with age and has been consistently higher in the age group 65 years and older (31.9%) (BRFSS, 2009). People with low income, low education, older than 54 years, divorced, widowed or separated and unemployed are at higher risk for diabetes (Pérez-Perdomo, 2004). The estimates for annual age-adjusted incidence of diabetes mellitus ranged from 5.0 to 12.8 per 1,000 persons among 40 states, the District of Columbia and Puerto Rico; with the greatest incidence observed in the South (10.5, 95% CI: 9.9%, 11.1%) and Puerto Rico (12.8, 95% CI: 10.0%, 15.5%) (CDC, 2008). The average annual incidence rate for 2005-2007 was 9.0 new cases of diabetes per 1,000 persons (95% CI: 8.6%, 9.4%). Moreover, in 33 of the participating states the incidence increased 90% from the period 1995-1997 to 2005-2007 (CDC, 2008).

According to the Puerto Rico Department of Health, the mortality rate of diabetes has been fluctuating from 59.6 per 100,000 habitants in 2000 to 56.6 per 100,000 habitants in 2008. (Department of Health, Diabetes Statistics, 2008). Diabetes is a disease that increases the risk of mortality and serious health complications. Therefore, people with diabetes become a target for public health strategies.

1.2.3. Caries in people with diabetes

There is substantial evidence to support the role of diabetes and poorer glycemic control as risk factors for periodontal disease (Silvestre et al., 2009, Mealey & Oates, 2006). However, the relationship between diabetes and dental caries is not consistent. Previous studies have hypothesized that several factors contribute to increased risk for caries due to increased glucose in saliva and gingival cervical fluid, decreased salivary flow and frequent intervals of food ingestion. The mechanism of increasing the risk is through an increase in the substrate available for cariogenic bacteria to metabolize and produce enamel- and dentin-demineralizing acids (Taylor et al., 2004). Therefore, people with diabetes could be at higher risk for dental caries and should be considered at time of oral health service.

1.3. Justification

In Puerto Rico, as in other countries around the world, the proportion of adults older than 65 years is increasing (Puerto Rico Census, 2000). During this century, public health interventions have been able to extend the life expectancy, but the challenge is to improve the quality of life for which the oral health is a very important component. Among elderly people, the oral health is associated with other systemic diseases because it can compromise the ability to eat and affect nutritional intake (Petersen and Yamamoto, 2005).

The development of caries in elderly is similar to the young, but older people have more risk factors for the development of caries, such as attachment loss, mouth dryness, presence of restoration, removable partial dentures, cognitive decline, and medical problems like stroke (Saunders & Meyerowitz, 2005). Therefore, it is important to measure these components as indicators of the oral and general health of the elderly.

Studies evaluating the relation between diabetes and caries are needed (Taylor et al., 2004). It is very important to evaluate if people with diabetes are at greater risk for caries to create prevention strategies focused on this population. As mentioned before, the poor oral health among older people has been evident in high level of tooth loss, dental caries experience and high prevalence of periodontal disease (Petersen and Yamamoto, 2005). These indicators should be a target for monitoring the oral health in people with diabetes as they are at higher risk for these oral diseases. People with diabetes suffer from different health complications, and the oral health can be affected as well and have to be considered at time of dental services. It is important for clinicians to identify all the risk factors for the development of dental caries in order to plan a treatment strategy.

No published data on caries prevalence to date are available in the elderly population in Puerto Rico. Therefore, it is very important to explore this area in order to meet the oral health needs among this age group, specifically among those with diabetes. Using the data provided by the study of Puerto Rican Elderly Dental Health Study (PREDHS), we evaluated the association between dental caries and diabetes in the non-institutionalized elderly population in Puerto Rico residing in San Juan.

CHAPTER 2: LITERATURE REVIEW

2.1. Dental Caries

2.1.1. Pathophysiology

The categories of dental caries that are mostly considered by clinicians and researchers are smooth-surfaces caries, pit and fissure caries, enamel caries, dentinal caries, secondary caries and early childhood caries. Dental caries can also be classified as coronal caries and root caries depending on where on the tooth it is located; on a coronal surfaces or root surface. The dental caries is a continuous process from the first atomic level of demineralization through the initial white spot, dentinal involvement to eventual cavitation (Featherstone, 2004). The mechanism of caries development depends on various events. The carbohydrates that are taken into the mouth are fermented by oral plaque bacteria and produces organic acids (lactic, formic, acetic and propionic). There are two major groups of bacteria that produce these acids: the *Mutans streptococci* and the *Lactobacilli* species. The acids diffuse into the enamel, dentin or cementum, and out from the tooth diffuses calcium and phosphate. This process is called demineralization, and if it continues then a cavity will eventually occur. The natural body repair mechanism for dental caries is remineralization and occur when calcium and phosphate together with fluoride diffuses into the tooth in non-cavitated lesion (Featherstone, 2004). As caries becomes progressive and more aggressive, the environment in the plaque becomes more frequently acidic and the aciduric bacteria survive at the expense of the other benign bacteria (Featherstone, 2004).

2.1.2. Caries detection

The white spot lesion is the earliest clinically visible sign of demineralization in an enamel surface. The syringe allows the dentist to dry the tooth and is useful in estimating the depth of penetration. A white post lesion that is visible when the enamel has been thoroughly dried has penetrated about half way through the enamel. A white or brown spot that is visible on a wet surface has penetrated all the way through the enamel, and the demineralization may be in the dentin (Fejerskov & Kidd, 2003).The dentist decides whether a cavity is present or not, and if it is just in the enamel or down to the dentin. The lesions that have penetrated through the dentin are irreversible while a lesion that has not affected the dentin is reversible (Burt & Eklund, 2005). The diagnosis serves as a guide to which the interventions might be considered for the patient. Sometimes additional information from radiographs and fiber-optic transillumination is needed (Fejerskov & Kidd, 2003). The measurement of caries in epidemiological studies has mostly been collected using the classical decayed, missing and filled (DMFS) index developed in the 1930's (Fejerskov & Kidd, 2003). The DMFS index has received universal acceptance and is the best known and most widely used of all dental indices (Burt & Eklund, 2005; Kingman & Selwitz, 1997). It is applied only to permanent teeth and not primary teeth. The DMFS index can be applied to whole teeth (DMFT) as well as for surfaces (DMFS). Each tooth has from four or five surfaces depending on the size of the tooth; for example, the incisor and canine teeth have four surfaces, while the pre-molar and molar teeth have five surfaces. Every person has a total of 128 teeth surfaces which during a lifetime is exposed to dental caries. Therefore, when the DMFS index is applied to teeth surfaces it describes three categories of surfaces; decayed surfaces (DS), missing surfaces (MS) and filled surfaces (FS). Because of the widespread removal of third molars in young adults, some prefer to record a score for 28 teeth instead of 32; therefore the index usually goes from 0 to 128 surfaces. Instead of teeth surfaces the index can be applied to whole teeth and classify them in the categories of decayed teeth (DT), filled teeth (FT) and missing teeth (MT). In this case the DMFT index takes values from 0 to 28, without the third molars. Because the number of affected surfaces is accumulative through time the DMFS index only has a meaning when age is stated. The DMFS index has some limitations because it does not directly give an indication of the intensity of the attack in any one individual and is not related to the number of teeth at risk, but is a simple count of those teeth that in the examiner's judgment have been affected by caries. Therefore, the index should always be interpreted with caution (Burt & Eklund, 2005). There are other indices that measure caries experiences; for example, the FS-T index measures the number of functioning teeth. This index takes into account the restorative aspect of dental health by counting the healthy and filled teeth and goes from 0 to 32 (Sheiham et al., 1987). Another index is the T-Health index which seeks to measure healthy teeth and gives a different numeric weight depending status of the tooth: 4 for a healthy tooth, 2 for a filled tooth and 1 when the tooth is decayed. Its purpose is to measure the influence of primary prevention or the responsibility taken by an individual towards dental health. The value of this index goes from 0 to 128 (Sheiham, et al., 1987). These two indices decrease with caries experience, while the DMFS index increases. The FS-T index has been shown to be a better index to differentiate people with poor oral health from better oral health, compared to the T-Health, DMFS and DMFT index. Among 1,991 dentate adults, 18% with the most caries experience were taken out as a risk group and were compared to the rest of the adults classified as non-risk group. The FS-T index was three times better to differentiate the two groups compared to DMFS and DMFT index and two times better than the T-Health index. In a multivariate logistic regression with socio-demographic variables, and use of dental services, the percentage of variance explained was 21.1% for the FS-T, 13.8% for the T-Health, 12.3% for the DMFS index and 7.6% for the DMFT index (Benigeri et al., 1998). Those results suggest the FS-Health is a better index to use for the detection of risk groups in terms of caries experience. However, the FS-T index has not been used in many studies. Additionally, the FS-T as well as the T-Health index also assumes that filled and missing surfaces are due to caries attack as does the DMFS index. In addition, they do not consider the evolution of caries associated factor over time. Therefore, they still have some of the same shortcomings as the DMFS index (Benigeri et al., 1998). Despite some limitations, the DMFS index has served as the primary outcome measure by which the relative efficacy of various caries preventive agents has been demonstrated in clinical trials. For example, it has been sensitive enough to detect the efficacy of a variety of fluoride delivery system, such as water fluoridation and mouthwash with fluor (Kingman & Selwitz, 1997).

2.1.3. Caries prevention strategies

As the dental caries is a continuous process it is possible to intervene in any stage with a therapeutic product or an intervention method. If the caries is detected early enough it is reversible (Featherstone, 2004). There are several guidelines for caries prevention for high-risk populations. The breakfast should be balanced with dairy products, grains and fruits to minimize the stimulation of sugar intake (Touger-Decker et al., 2003). The number of meals including snacks should be limited to about four because this gives time for sugar clearance. Sticky sugar-containing products should be eliminated and fiber-rich products should be consumed as these require chewing, which stimulates salivary flow (Mount et al., 2005). It is also recommended tooth-brushing before and after every meal to limit the drop of the pH in the saliva. People with reduced salivary flow should use sugarless fluoride chewing gum for 20 minutes after every meal (Axelsson, 2000). Substituting the fermentable carbohydrates for non-cariogenic sweeteners like xylitol is effective to reduce the caries progress (Featherstone, 2004).

The fluoride helps to reverse the progress of cavity through the process of remineralization and has been a strategy to reduce the caries development (Touger-Decker et al., 2003). The use of fluoride products like toothpaste, mouthwash and office topicals have been shown to reduce caries between 30% and 70% compared with no fluoride therapy. The fluoridation of the drinking water has also been effective in reducing the severity of dental decay in entire populations (Featherstone, 2004).

2.2. Risk factors for dental caries

Dental caries is a complex interaction of etiologic factors and many modifying risk and protective factors (Axelsson, 2000). The pathological risk factors are aciduric bacteria, frequent ingestion of carbohydrates and reduced salivary flow (Featherstone, 2004). On the other hand, the protective factors are salivary flow, ingestion of proteins, calcium, phosphate, fluoride, protective dietary components and non-cariogenic sweeteners. The balance between these factors determines if the lesions progress, remain unchanged or reverse (Featherstone, 2004).

2.2.1. Demographic variables

One of the most commonly studied factors is the socio-economic status, as it is an indicator of inequality for general and dental health (Axelsson, 2000). The results of various studies indicate that caries increases with age. The groups of older adults are the group with higher caries experience (Beltrán-Aguilar et al., 2005). Among people with low education level the irregular attendance to a dentist is more common (Axelsson, 2000). Paulander et al. (2003) indicates that adults with low education tend to have fewer intact tooth surfaces and a significantly poorer occlusal function (Paulander et al., 2003). This difference in dental status is attributable to the fact that highly educated people know how to learn from written information, to seek information about health promotion and to apply theoretical information, for example, self-care (Axelsson, 2000).

2.2.2. Behavioral factors

On the other hand, the behavioral factors that are more related to caries are diet, oral hygiene, and dental habits. The intake of fermentable carbohydrates (for example, glucose and sucrose) will result in a drop in pH surface in the plaque and on the underlying tooth surface where some demineralization may occur. Sucrose, glucose and fructose are therefore considered to be highly cariogenic (Axelsson, 2000). Frequency of consumption is a significant contributor to the cariogenicity of the diet because of the time that sugars are available to microorganisms in the mouth. Higher frequency of fermentable carbohydrate intake means more demineralization and less remineralization which lead to cavity progress (Touger-Decker et al., 2003). On the contrary, when diet has a high content of calcium, phosphate and protein, as in dairy products, it may favor the remineralization (Touger-Decker et al., 2003).

Caries development is related not only to diet but also to oral hygiene practices. Experimental studies have shown that frequent sugar intake is not an etiologic factor but an external modifying risk factor for development of caries on tooth surfaces covered with cariogenic plaque. In other words, even if there is a large intake of sugar it will not produce caries if there is a good oral hygiene (Axelsson, 2000). Clinical trials with fluoridated toothpaste have shown that caries can be prevented by adequate oral hygiene with the use of fluoridated tooth paste and show the importance of brushing the teeth with fluoride toothpaste (Touger-Decker et al., 2003).

2.2.3. Smoking

It has been found that adult smokers have a higher prevalence of caries than adults that do not smoke (Axelsson et al., 1998). A sample of 1,093 subjects aged 35 to 75 years old, were clinically examined and interviewed regarding their tobacco habits, hygiene habits and dietary habits. It was found that the number of missing teeth was higher in smokers than in non-smokers with a difference of 0.6 in the 35-49 age group, 1.5 in the 50-64 age group and 5.8 in the 70-74 age group. The index for decayed and filled and surfaces (DFS) was also higher for smokers. Decayed surfaces were 0.3 in non-smokers and 1.5 in smokers (p-value>0.05), while the filled surfaces were 30.9 for non-smokers and 37.5 for smokers (p-value<0.05) (Axelsson et al., 1998).

2.2.4. Saliva

Saliva is produced by three pairs of major salivary glands (parotid, submandibular, and sublingual) plus numerous minor salivary glands. It contains inorganic constituents like bicarbonate that allow buffering of the pH level, calcium and phosphate that keep maintenance of the teeth mineral integrity. In addition, it contains a variety of proteins that are important to the oral health (Dodds et al., 2004). Because of these properties the saliva is an important protective factor against the caries development. Therefore, the reduction in salivary flow could be a risk factor for caries development because it would provide less protection and less ability for the saliva to enhance remineralization, remove bacteria or inhibit bacterial action (Featherstone, 2004). Certain subpopulations as elderly and people with certain systemic diseases (diabetes and hypertension) seem to have comprised salivary flow (Dodds et al., 2004).

2.3. Diabetes mellitus

2.3.1. Definition

Diabetes mellitus is a group of metabolic disorders of multiple etiologies, characterized by chronic hyperglycemia with disturbances in carbohydrates, fat and protein metabolism (WHO, 1999; ADA, 2010). The basis of these abnormalities is deficient action of insulin of target tissues, which results in inadequate insulin secretion and diminished response to insulin in the hormone action (ADA, 2010). The impairment of insulin secretion and defects in insulin action can coexist in a person and sometimes it can be unclear which abnormality is the primary cause of the hyperglycemia. Some of the symptoms of diabetes include, polyuria, polydipsia, blurring vision and weight loss, sometimes with polyphagia; although patients can be asymptomatic for a long period of time (WHO, 1999; ADA, 2010).

2.3.2. Classification

In 1980, the Expert Committee on the Diagnosis and Classification of Diabetes Mellitus proposed two major classes of diabetes mellitus and named them type 1 and type 2 (WHO, 1999). Years later, two other classification from the WHO's report from 1985 were included in the 10^{th} revision of the International Classification of Diseases (ICD-10) in 1992. These two classes are impaired glucose tolerance (IGT) and gestational diabetes mellitus (GDM) (WHO, 1999). The clinical stage of impaired fasting glycaemia (IFG) was introduced in the WHO report of 1999 and classifies individuals who have an intermediate stage of glucose values above the normal range but below those of diabetes diagnosis (WHO, 1999).

The classification of diabetes can be made according to the etiology type or clinical stage. The etiological classification divides diabetes into type 1 and type 2. Type 1 diabetes, also called insulin-dependent diabetes or juvenile-onset diabetes, is characterized by pancreatic β-cell autoimmune destruction usually leading to absolute insulin deficiency. The rate of β-cell destruction can vary from very fast among children to slow in adults. These individuals are prone to ketoacidosis and it may be the first and early manifestation of the disease (ADA, 2010). Some people may retain some β-cell function that produces insulin sufficient to prevent ketoacidosis, but eventually the amount of insulin secretion is not enough and makes the individual dependent of insulin (ADA, 2010). This type of diabetes accounts for only 5-10% of the cases and have multiple genetic predisposition as well as environmental factors (ADA, 2010). It is also important to mention that some forms of type 1 diabetes include idiopathic diabetes, which has no known etiologies (WHO, 1999). It is strongly inherited and lacks immunological evidence for β-cell autoimmunity (ADA, 2010).

Type 2 diabetes is a result from defects in insulin secretion and it classifies individuals who have relative (rather than absolute) insulin deficiency (WHO, 1999). It can range from predominantly insulin resistance with relative insulin deficiency to predominantly an insulin secretory defect with insulin resistance. As a result, these patients appear to have normal or elevated blood glucose levels that are higher than expected (ADA, 2010). They do not need insulin treatment to survive at least in the first stages of the disease (ADA, 2010). There are many risk factors for type 2 diabetes and a specific etiology is not known but by definition β-cell destruction does not occur (ADA, 2010). Because the hyperglycemia is often not severe enough to provoke noticeable symptoms the type 2 diabetes is frequently undiagnosed for many years. Ketoacidosis is infrequent in this type of diabetes, but can be seen in association with stress or infection. Many of the patients are obese which by itself causes insulin resistance, and body fat accumulated in the abdominal area is a risk factor. Insulin sensitivity may be increased by weight reduction, increased activity or pharmacological treatment of hyperglycemia but is not restored to normal (WHO, 1999). The risk for developing diabetes type 2 increases with age, obesity, and lack of physical activity (Grundy, 2006; Avenell et al., 2004). It is strongly associated with genetic predisposition although the genetics is complex and not clearly defined (ADA, 2010). Type 2 diabetes represents the 90-95% of the diabetes cases (WHO, 1999).

The clinical stage reflects the degrees of hyperglycemia which allow a person to be categorized by stage according to the clinical characteristics even in the absence of information of the underlying etiology (WHO, 1999). A person can be classified as having a normal blood glucose levels if the fasting blood glucose levels are below <100 mg/dl (5.6 mmol/l). Two intermediate stages are the impaired fasting glucose (IFG) and impaired glucose tolerance (IGT), which classifies a person with high glucose levels but not enough to diagnose diabetes. According to the American Diabetes Association (ADA, 2010), a person with IFG has fasting plasma glucose levels (FPG) between 100 mg/dl (5.6 mmol/l) and 125mg/dl (6.9mmol/l). For these individuals a two-hour oral glucose tolerance test (OGTT) is not recommended but if it is measured the levels should be below 200 mg/dl (11.1mmol/l). For a person to be classified as having IGT, the values from an OGTT should be between 140 mg/dl (7.8 mmol/l) and 199 mg/dl (11.1 mmol/dl). Rather than being seen as clinical entities they are categorized as a stage in the natural history of disordered carbohydrate metabolism. The stage of IFG and IGT are risk factors for future development of type 2 diabetes and therefore refereed as having “pre-diabetes”. These categories are risk factors for cardiovascular and also associated with metabolic syndrome which includes obesity, atherogenic dyslipidemia and hypertension (Grundy, 2006). It is also important to mention that many of these individuals have normal or near normal glucose levels in their daily lives (ADA, 2010).

2.3.3. Diagnosis

The clinical diagnosis of diabetes is often based on symptoms such as increased thirst and urine volume, recurrent infections, unexplained weight loss and in some cases drowsiness and coma. The diagnosis in an asymptomatic subject is made on the basis of several glucose values. Additional to an abnormal glucose test, a plasma glucose test or oral glucose tolerance test should be done on two different occasions to confirm the diagnosis (WHO, 1999). In an asymptomatic person if the samples fail to confirm the diagnosis of diabetes, it is usually advisable to maintain surveillance with periodic re-testing. There are three criteria for a diagnosis of diabetes mellitus (Table 2.1). The first is having FPG ≥126 mg/dl (7 mmol/l) where no caloric intake can be made during 8 hours. The other criteria are having symptoms of hyperglycemia and casual plasma glucose ≥200 mg/dl (11.1 mmol/l) at any time of the day. The third is based on an OGGT with two-hour plasma glucose ≥200 mg/dl (11.1 mmol/l) with the glucose load containing the equivalent of 75 g anhydrous glucose dissolved in water. In the 2010 report, the American Diabetes Association adds the criteria of having glycosylated hemoglobin of at least 6.5%. All these criteria have to be in the absence of unequivocal hyperglycemia and confirmed by repeat testing in a different day (ADA, 2010). Other factors like ethnicity, family history, age and adiposity can also be considered (WHO, 1999).

Table 2.1. Criteria for the diagnosis of diabetes (ADA, 2010).

1. A1C≥6.5%. The test should be performed in a laboratory using a method that is National Glycohemoglobin Standardization Program (NGSP) certified and standardized to the Diabetes Control and Complications Trial (DCCT) assay.* OR
2. FPG ≥ 126 mg/dl (7.0 mmol/l). Fasting is defined as no caloric intake for at least 8 hours.* OR
3. Symptoms for hyperglycemia and a casual plasma glucose ≥ 200 mg/dl (11.1 mmol). Casual is defined as any time of day without regard to time since last meal. The classic symptoms of hyperglycemia include polyuria, polydipsia, and unexplained weight loss.* OR
4. 2-hour plasma glucose ≥ 200 mg/dl (11.1 mmol/l) during an OGTT. The test should be performed as described by the World Health Organization, using a glucose load containing the equivalent of 75g anhydrous glucose dissolved in water.

*In the absence of unequivocal hyperglycemia, criteria 1–3 should be confirmed by repeat testing.

2.3.4. Morbidity and mortality

People with diabetes are at risk of cardiovascular, peripheral vascular and cerebrovascular disease. Other effects are complications of retinopathy with potential blindness, nephropathy that may lead to renal failure, and neuropathy with risk of foot ulcers, amputation, charcot joints, autonomic dysfunction and sexual dysfunction.

Uncontrolled diabetes mellitus leads to biodermal imbalances that can cause acute life-threatening events such as ketoacidosis and hyperosmolar syndrome (ADA, 2010). Elderly adults have, in addition, greater risk for disabilities related to mobility and daily tasks such as walking, do housework and prepare meals (Gregg et al., 2002). A national cohort study evaluated the mortality and morbidity on a sample of 148,562 elders with diabetes. In every age group, elders with diabetes had significantly higher all-cause mortality rates than the general population (Standardized Mortality Rate (SMR) = 1.41; 95% CI: 1.39-1.43). The most common complication in diabetes patients were ischemic heart disease and stroke with incidence rates of 181.5 and 126.2 per 1,000 person-years respectively. Other complications were also present including lower extremity infection and hypoglycemia. After adjusting for age, women had higher hazard ratio (HR) for hypoglycemia (p-value<0.05) (HR = 1.28), hyperosmolar syndrome (HR = 1.19), ketoacidosis (HR = 1.17), and blindness (HR = 1.22), but lower risk (p-value<0.001) for amputation (RH = 0.70), gangrene (RH = 0.78), acute myocardial infarction (RH = (0.80) and ischemic heart disease (RH = 0.88) (p-value<0.05) when comparing to men (Bertoni et al., 2002). The age-standardized mortality rate was 62.3 per 1,000 in women and 81.8 per 1,000 in men, using the age distribution of the U.S population aged 65 years and older in 1990. It increased with age similarly in men and women. The age-adjusted relative risk of mortality for men with diabetes was 1.34 (95% CI: 1.31-1.38) compared to women (Bertoni et al., 2002).

2.3.5. Oral complications in people with diabetes

Diabetes causes several health complications including oral diseases as periodontal diseases, dental caries and xerostomia (Soell et al., 2007). It has been suggested that diabetes is a risk factor for periodontitis and gingivitis (Soell et al., 2007). Gingivitis is characterized by a reversible inflammation of gingival tissue caused by the presence of bacterial plaque. In elderly individuals, the inflammation develops much faster after plaque accumulation. On the other hand, periodontal disease is an irreversible inflammatory disease that extends deep into the tissues adjacent to the teeth and causes loss of supporting connective tissue and alveolar bone. It results in soft tissue pockets, tooth loss pain, discomfort and impaired mastication. Diabetes has also been associated with xerostomia, defined as a diminished salivary flow caused by malfunction in the salivary glands and causing difficulties in chewing, swallowing, tasting and speaking. It has been documented that in patients with type 2 diabetes, the salivary secretions from the submandibular and sublingual glands are reduced (Soell et al., 2007).

2.4. Association between caries and diabetes

2.4.1. Coronal caries and diabetes

Data on the relation between caries and diabetes is not consistent. Two hypotheses have been proposed to understand this relation. Studies that observed higher caries experience in people with diabetes argument that increased glucose level in saliva and decreased salivary flow increase the risk for caries. In addition, it has been hypothesized that people with diabetes have more frequent intervals of food ingestions which reduces the pH in the oral cavity and increases the caries risk (Hintao et al, 2007; Moore et al, 2001; Taylor et al., 2004). In contrast, other studies indicate that people with diabetes have lower risk for dental caries because of restricted sugar diet, increased protein intake and delayed eruption of permanent teeth (Tavares et al, 1991; Taylor et al., 2004).

Albrecht et al. (1988) found that among people aged 15 to 55, the average DMFT index was always higher in people with diabetes than in controls, though the difference was not always statistically significant in every age group. The oral hygiene was always worse in people with diabetes compared with the people without diabetes (p-value<0.001). Among people with diabetes, the D component was always lower across all the age groups and the F component always higher than the control group. This study suggests that the dental care of people with diabetes is probably responsible for the reduction in the number of carious teeth and the higher F value. Still, the sucrose-free diet does not seem to reduce the prevalence of caries. The M component was also higher in the people with diabetes due to periodontal disease.

A study in the United Kingdom from 1992 evaluated the oral health in a subsample of approximately 300 subjects with diabetes between the ages of 16 to 75. Oral examinations were made to assess the decayed, filled and missing teeth index (DMFT) for caries experience, and a questionnaire gathered information on oral treatments, oral problems and perceptions of their oral health. The results from the subjects with diabetes were compared with the general population recollected from the same dental survey. The total average of DMFT index was significantly higher (19.5) for the subjects with diabetes compared with the general population (16.0) (p-value<0.001). This trend was consistent in all the other components with the biggest difference in missing teeth, although not significantly different (p-value>0.05). In addition, people with diabetes reported more oral self-care in comparison with the general population. The significantly higher DMFT index could not be explained only by the M- or F-component because the subjects with diabetes had also more decayed teeth (Jones et al., 1992). A study conducted 1993 in Baltimore found that people with diabetes had more decayed surfaces compared to participants without diabetes (3.8±9.5 vs. 0.7±1.7) (p-value<0.01). The participants were older with a range of 60-68 years and the controls were matched by age and sex. They also found that participants with diabetes had more plaque, gingival bleeding and calculus compared to controls, which suggest that the oral hygiene was worse among those with diabetes and might affected the development of caries (Cherry-Peppers &Skip, 1993).

A cross-sectional study (1999) with a convenience sample of 42 non-institutionalized adults recruited from Michigan, evaluated the relation between caries and diabetes only in older adults age 54 to 86 years. From this sample, 24 subjects had diabetes and 18 did not have diabetes. Subjects with a positive history of diabetes were confirmed by a fasting plasma glucose test and were treated with dietary modifications, oral hypoglycemic agents or insulin. Subjects without a history of diabetes were confirmed by an oral glucose tolerance test. An oral examination was performed on all the subjects and the number of decayed, missing and filled surfaces (DMFS) in the coronal and root caries, and the percentage of decayed, missing and filled surfaces (DMFS%) were determined. The data of third molars were included in the analysis and due to various causes of tooth loss the M component of the DMFS was not included in the overall caries experience analysis. The results showed that the overall caries experiences, combining the coronal caries and root caries, was lower for subjects with diabetes than subjects without diabetes (DFS = 57.2±33.8 and DFS = 79.7±30.9, respectively; p-value=0.03). This was consistent in the coronal caries (DFS = 41.3±20.9 and DFS = 54.9±20.3, respectively; p-value=0.04) and the root caries (DFS = 15.9±16.3

and DFS = 24.7±13.8, respectively; p-value=0.07). In the separate component, the subjects with diabetes tended to have almost twice the decayed surfaces than those without diabetes (DS = 3.1 ± 4.0 and DS = 1.6 ± 1.8; p-value=0.11) and more missing surfaces (MS = 102.4±63.6 and MS = 69.7±52.5; p-value=0.08). These results suggest that older adults with diabetes may have more active dental caries and tooth loss than adults without diabetes (Lin et al., 1999).

Different results have been reported by other studies. A study with 222 diabetes patients from a diabetes center and 189 subjects without medical history of diabetes from the general population made clinical examinations to assess the DMFT. The average of the DMFT score was non-significantly (p-value>0.05) higher in the group with diabetes (17.7 ± 6.9) than in the group without diabetes (14.9 ± 6.7). The mean of missing teeth was significantly higher among people with diabetes (12.3 ± 7.3) than without diabetes (9.7 ± 7.1) (p-value <0.001), but there were no significant differences in the decayed and filled teeth (p-value>0.05). People with type I diabetes were found to have a significantly higher number of teeth with fillings than those with type II diabetes (p<0.001). However, the latter group had a significantly higher number of extracted teeth (p<0.001) (Bacic et al., 1989). A later study conducted in 1991, with 88 subjects with diabetes type 1 and 185 controls, found that participants with diabetes had significantly more missing teeth (9.7±5.4 vs. 7.8±4.7; p-value<0.001) compared to controls. A dietary questionnaire administered to 60 participants observed that the majority of participants with diabetes had a restricted diet; this observation might have partially explained the fact that differences in decayed and filled surfaces were not significantly different (Tavares et al., 1991). In 2001, these results were replicated in Pittsburgh, when 390 subjects with diabetes type 1 were compared to 202 controls without diabetes. Although there was a significantly higher DMFS index among the participants with diabetes (33.7±1.2 vs. 26.2±1.7; p-value<0.001), the finding was due to more missing teeth (2.51±0.8 vs. 1.44±0.28; p-value<0.01) and not decayed or filled (DFS: 21.7±0.8 vs. 19.1±1.2; p-value>0.05). Among subject with diabetes factors significantly associated with DFS, were frequent use of dental floss and visits to the dentist; these findings might explain the non-significantly higher DFS index (Moore et al., 2001). The latest study, that found similar results was conducted in 2007 with 46 patients with diabetes type 1, 40 with diabetes type 2 and 50 controls. The findings confirmed the results from earlier studies, with a higher DMFS index among those with type 1 diabetes (46.42±32.33) and type 2 diabetes (38.17±29.88) compared to controls (21.64±29.36) (Ilgüy et al., 2007). The group with type 2 diabetes had the highest number of missing surfaces (32.40±27.31) compared to type 1 diabetes (23.04±24.86) and controls (8.04±9.00). In summary, these four studies point out the fact that participants with diabetes tend to have more missing teeth, and it has been suggested that predisposition to periodontal diseases among people with diabetes might explain these findings.

There is also evidence that oral health worsens with poor glycemic control. Lin et al., (1999) compared the oral health among participants with controlled (HbA1c ≤ 9%) and poorly controlled (HbA1c > 9%) diabetes with controls. There was a pattern of increasing missing surfaces and active caries lesions as glycemic control worsened. Participants with poorly controlled diabetes compared to well controlled diabetes and controls had the greatest numbers of decayed (3.4±4.5 vs. 2.7±3.2 vs. 1.6±1.8, respectively; p-value>0.05) and missing surfaces (118±67.7 vs. 75.8±48.2 vs. 69.7±52.5, respectively; p-value=0.05). During a three-year follow up study of children with type 1 diabetes, children with poor glycemic control (HbA_{1c}>8.0%) had more new active caries lesions (DS = 4.8 ± 7.8) compared to children with good metabolic control (DS = 1.4 ± 1.9). The most important determinants for caries development among children with diabetes was metabolic control (OR = 5.7; p-value<0.05) and poor oral hygiene (Visible Plaque Index>25%) (OR = 6.8; p-value<0.05) (Twetman et al., 2002). However, no correlation or association was found between glycemic control and caries outcome in other studies (Hintao et al., 2007; Basic et al., 1989).

Finally, there are studies that have not found differences across diabetes status. One study compared 12 subjects with type 1 diabetes and 32 controls matched by sex and age, selected from the Helsinki Aging study. From the oral exam only decayed teeth were considered, and the results were similar in the two groups (participants with diabetes, 2.0±2.0 and controls, 2.5±2.5) (Närhi et al., 1996). Another study performed an oral exam among 92 older adults; 25 had type 2 diabetes and 67 were controls. They compared both DMFT and the individual components of the index. The results showed no differences between the participants with diabetes and controls in DMFT (23.8±6.0 vs. 25.1±4.3), decayed (4.7±7.8 vs. 3.5±6.3) or filled surfaces (18.3±20.9 vs. 21.1± 19.5) (Collin et al., 1998). Hintao et al. (2007) also reported similar findings when comparing 105 participants with type 2 diabetes with 103 participants without diabetes selected from a hospital in Thailand. A marginally higher mean of decayed and filled surfaces was found among the participants with diabetes (DFS: 8.0±9.4 vs. 6.3±7.5). The results of the multivariate model suggested no differences in decayed and filled surfaces across diabetes status (OR = 1.08; 95% CI: 0.98–1.50) (Hintao et al., 2007). A two-year follow-up of children with type 1 diabetes from the Lithuanian Diabetes Register found no differences in caries outcome at baseline (DMFS = 23.0± 15.0 vs.27.0±16.0) and after 2 years (DFMS = 34.5±166.6 vs. 37.1±15.1) compared to controls. The number of decayed, filled and extracted surfaces was also similar in both groups in the two-year examination (Siudikiene et al, 2008). These results contrast the findings of Twetman et al., (2002) in his longitudinal study over a three–year follow-up period where there was an association between glycemic control and decayed surfaces.

2.4.2. Root caries and diabetes

Fewer studies have considered the relation between root caries and diabetes. One of the studies assessed the prevalence of root caries in subjects with diabetes and subjects without diabetes. Subjects with diabetes were selected from a diabetes center in Massachusetts and the control group was selected from a large–scale root caries study. Coronal and root caries were assessed in 88 subjects with type 1 diabetes and 105 controls between the ages of 45 and 65. A dietary survey was made on a sub-sample of 30 subjects with diabetes and 30 without diabetes to evaluate restricted diet. The results for root caries were significantly (p-value<0.05) different in the two groups as the Katz Root Caries Index scores (for which lesions are calculated as a percentage of the numbers of exposed root surfaces) were 7.06 for people with diabetes and 15.24 for people without diabetes. These results suggest that people with diabetes have fewer affected root surfaces, partially attributed to a restricted ingestion of refined carbohydrates among the subjects with diabetes (Tavares et al., 1991). However, another study that also evaluated participants with type 1 diabetes found different results. A group of 390 subjects with diabetes were selected from an epidemiological study from the University of Pittsburgh, whereas controls (n=202) were selected among spouses or friends of the participants or recruited from the community. Both participants with diabetes and controls had similar age (32.6±0.4 vs. 33.0±0.5, respectively). A higher prevalence of root caries was observed among subjects with type 1 diabetes than among controls (16% vs. 8.4%) (p-value<0.01) (Moore et al., 2001).

Hintao et al. (2007) found that type 2 diabetes patients, when compared with healthy people, had a higher prevalence of root surface caries (40% vs. 18.5%; p = 0.001), a higher number of decayed and filled root surfaces (1.2 ± 0.2 vs. 0.5 ± 0.1; p<0.01) and a higher generalized periodontitis (98.1% vs. 87.4%; p<0.01). Other three studies that also evaluated root caries found no significant differences across diabetes status (Närhi et al., 1996; Collin et al., 1998; Lin et al., 1999).

In summary, there is not a clear relation between diabetes and coronal or root caries as the findings of diverse studies have been very different. The analysis in many of these studies has been limited and the small sample sizes could have affected the ability to detect any potential associations. The sample groups have also varied in terms of diabetes type and age range, which could explain the variety of results. Furthermore, both diabetes and caries are multifactorial diseases these risk factors have to be addressed in the studies in order to understand the relation between these two conditions.

Table 2.2 Synthesis of literature review

Author	Year	Study Design	Sample	Relevant Findings
Albrecht et al	1988	Case-control	1,277 patients with diabetes under care were examined between 1975 and 1982. Postprandial blood glucose determination was performed regularly. The controls were 625 textile workers. The participants were aged 15 years an older	DMFT was always higher in patients with diabetes than in controls though the difference was only significant in the age groups 15-19 years, 30-34 years and 55 years and over (p-value<0.001). The gingivitis (PI) was more pronounced and oral hygiene (OHI-S) was always worse in patients with diabetes compared with the controls in every age group (p-value<0.001). In the patients with diabetes the D-component was always lower and the F- and M-components were always higher among participants with diabetes than the control group. The length of diabetes did not affect PI values. No correlation was found between changes in blood glucose levels and the severity of gingivitis. It is suggested that the dental care is probably responsible for the reduction of carious teeth and the higher F value. A high PI value supports that the high M value is due to periodontal disease.
Ismail et al.	1990	Cross-sectional (HHANES-Hispanic Health and Nutrition Examination Survey)	N = 9401 5,983 Mexicans 1,192 Cubans 2,226 Puerto Ricans 5-74 years	In adults, Puerto Rican and Cubans had at least 40% higher mean number of filled teeth than Mexicans Puerto Ricans and Cubans had approximately two times more missing teeth. Hispanic adults had twice higher mean number of decayed teeth than Hispanic children.

Author	Year	Study Design	Sample	Relevant Findings
Tavares et al.	1991	Case-control	88 patients with diabetes were selected from patients at a diabetes center. They were aged 45-65 years, had a 10-year history of type 1 diabetes, and with moderate to poor control of their diabetic condition demonstrated by high tests (HbA_{1c} >11% and ≥11 mml/L) over the last 10 years. 185 controls with the same age range were self-selected via newspaper and radio. All the participants had a minimum of 10 teeth and three sites with recession (1 mm). 30 participants with diabetes and 30 without diabetes were administered a dietary questionnaire.	Participants with diabetes had more missing teeth than the controls (9.70±5.39 vs. 7.80±4.69, respectively) (p-value<0.001). The participants with diabetes had 24% (DFS%) of their coronal surfaces decayed or filled compared to 28% among the controls (p-value=0.02). There was a significant difference in the Katz Root Caries Index that was 15.2 for the controls and 7.1 for diabetics (p-value<0.001) Filled root surfaces were significantly higher among controls (1.76±2.78) than patients with diabetes (0.49±1.01) (p-value<0.001). 28 participants with diabetes reported a moderate to complete restriction of sugars and starches in their diets compared to only 1 participant without diabetes (p-value<0.001). It is suggested that these findings could be the results of restricted ingestion of refined carbohydrates by the group with diabetes.

Author	Year	Study Design	Sample	Relevant Findings
Jones et al.	1992	Case-control	309 patients with diabetes attending a diabetes clinic in Nottingham were selected. They had: 1) at least 1 natural tooth 2) answer a dental survey, and 3) underwent an oral exam. 202 had a history of insulin treatment and 107 with oral agents. The 593 controls were participants in a dental health survey (1988) in the UK.	Participants with diabetes had a higher DMFT score compared to healthy controls (16.0 vs. 19.5; 99% CI: 18.0-21.0). They also had a higher mean in each of the components, although not significant. The group with diabetes had fewer sound and untreated teeth compared to controls (12.5 vs. 16.0; p-value<0.001). The group with diabetes treated with insulin had a higher DMFT score compared to those treated with tablets or diet (20.1 vs. 17.4; p-value<0.001). They also had a higher mean in each of the components, although not significant. Patients with diabetes reported the following perceived oral health and behavior: 16% reported mouth ulcers and 31% reported bleeding gums in the last 4 weeks. No differences in these self-reported oral health problems between those who were taking insulin and tablets or diet (no comparison with controls available). Patients with diabetes who were treated with insulin were more likely to report regular dental visits (61% vs. 45%; p-value<0.005) and to clean their teeth once or more a day (94% vs. 83%; p-value<0.001), compared to those who were treated with tablets or diet. It is suggested that the population with diabetes are more caries prone because the higher DMFT score was not only confined to missing teeth (explained by periodontal disease) or restored teeth (explained by early caries intervention) but also had more decayed teeth.

Author	Year	Study Design	Sample	Relevant Findings
Cherry-Peppers & Ship	1993	Case-control	All subjects were participants in the oral physiology components of the Baltimore Longitudinal Study of Aging. According to an OGGT test (WHO criteria), 11 subjects had type 2 diabetes, 32 subjects had Impaired Glucose Tolerance (IGT) and 43 age- and gender matched controls were identified. The mean age was 67.9±11.1 years among participants with diabetes, 60.7±19.1 years among the subjects with IGT and 60.2±16.8 among controls. Diabetes status was evaluated by measuring HbA_{1c}.	The group with type 2 diabetes had more surfaces with coronal caries compared to participants with IGT and controls (3.8±9.5, 0.6±1.2 and 0.7±1.7, respectively). The group with IGT had more missing surfaces compared to the group with type 2 diabetes (29.0±36.7 vs. 20.3±19.6). No differences were found between the three groups in DMFS score or filled surfaces. The group with type 2 diabetes had a greater prevalence of sites with dental plaque (50% vs. 30%), gingival bleeding (25% vs. 15%) and calculus (25% vs. 10%) compared with the control group (p-value<0.01). The group with IGT also had an increased percentage of sites with calculus compared with the control group (15% vs. 10%) (p-value<0.01). No statistical differences between the three groups were found for periodontal measurements (recession, pockets and attachment loss) or oral mucosa. It is suggested that the increasing number of surfaces with coronal caries may be a consequence of a poorer glycemic state among subjects with diabetes.

Author	Year	Study Design	Sample	Relevant Findings
Närhi et al.	1996	Case-control	The study population included subjects that completed the oral health component of the Helsinki Aging Study (HAS), a population-based health study. Subjects with diabetes were identified using the following criteria: 1) a previous diagnosis of diabetes mellitus 2) medical treatment or 3) fasting glucose test (>7.mmol/L). Final study group consisted of 12 subjects with type 2 diabetes, 20 subjects with type 2 diabetes in addition to CVD and 32 age-and sex-matched healthy controls. The age range of the study population was 76-86 years.	No differences were found in number of decayed teeth between the group with diabetes (2.0±2.0), diabetes in addition to CVD (3.1±4.6) and controls (2.5±2.5) (p-value<0.05). No differences were found in the Root Caries Index between the subjects with diabetes (34.8±44.5), diabetes in addition to CVD (19.8±30.2) and controls (19.0±29.2) (p-value>0.05). The number of medications used daily was significantly higher in the subjects with type 2 diabetes and CVD (3.6±2.3), than in the group with diabetes only (0.8±0.8) and the controls (0.2±0.5) (p-value<0.001). Unstimulated saliva flow rates were significantly lower in women (0.11±0.13) than in men (0.23±0.23) (p-value=0.02). A significant correlation was found between the number of medications and unstimulated saliva flow rate (r_s=-0.29, p=0.03). No significant differences were found in salivary flow rates among the three groups. No significant differences were found in the pH level or growth of salivary *Mutans streptococci*. The growth of salivary microorganisms did not correlate with the subjects' blood glucose levels or with the number of medications.

Author	Year	Study Design	Sample	Relevant Findings
Collin et al.	1998	Case-control	All participants were recruited for study in 1979-1981 from Kuopio, Finland. The participants with type 2 diabetes were clinically diagnosed and confirmed with an OGTT test. All participants underwent an oral examination in 1994. The final study population consisted of 25 subjects with diabetes with a mean age of 67±5.5 years and 40 controls with a mean age of 66±5.1 years.	No significant difference was found in DMFT when comparing participants with diabetes (23.8±6.0) with participants without diabetes (25.1±4.3) (p-value>0.05). There were no differences between participants with diabetes and without diabetes in terms of percentage of decayed surfaces (4.7±7.8 vs. 3.5±6.3) or percentage of filled surfaces (18.3±20.9 vs. 21.1± 19.5) (p-value>0.05). There were no differences between participants with diabetes and without diabetes in terms of percentage of decayed root surfaces (2.2±5.2 vs. 2.5±5.2) or filled root surfaces (2.9±7.2 vs. 1.8±4.7) (p-value>0.05). A salivary flow rate of >0.8 ml/min was associated with an increased caries prevalence (OR=6.5; 95% CI: 0.84-50.2) in comparison with a lower salivary flow rate. Microbes and yeast did not differ in both groups. In addition, no association was found between caries and artery disease/hypertension. It is suggested that the occurrence of caries and acidogenic microbes was not increased in elderly patients with type 2 diabetes. However, a salivary flow of at least 0.8 ml/min was paradoxically associated with caries in patients with type 2 diabetes.

Author	Year	Study Design	Sample	Relevant Findings
Lin et al.	1999	Cross-sectional	Convenience sample of community living older adults from Michigan. All subjects were 54 years and older and had at least 1 natural tooth present. Subjects had a positive history of diabetes mellitus for at least 6 months and confirmed by a fasting plasma glucose test. Nine subjects were well-controlled ($HbA_{1c} \leq 9\%$) and 15 were poorly controlled ($HbA_{1c} > 9\%$). Subjects without diabetes were confirmed by a normal oral glucose tolerance test. The total sample was 42 subjects; 24 with diabetes and 18 without diabetes.	The overall caries experience (coronal and root caries) was significantly lower for subjects with diabetes than those without diabetes. Participants with diabetes had lower FS but higher DS and MS than controls. Decayed surfaces in patients with diabetes (3.1± 4.0) were nearly twice that of controls (1.6±1.8) ($p=0.11$). In coronal caries the results were similar; controls had higher DFS and more filled surfaces, whereas those with diabetes had more active caries lesions and missing surfaces. These differences were not statistically significant when adjusted by the percentage of available surfaces (DFS%, FS%, DS%) The decayed and filled surfaces combined (DFS) and filled surfaces alone (FS) were consistently higher in controls, decreased in well controlled diabetes and even lower in poorly-controlled diabetes. There was a pattern of increasing missing surfaces (MS) and active caries lesions (DS) as glycemic control worsened. Similar results for active caries and missing surfaces were found between well-controlled diabetes and those without diabetes. Whereas patients with poorly controlled diabetes had the greatest number and percentage of active caries (DS) and missing surfaces (MS). For root caries there were no significant differences in glycemic control other than missing surfaces (MS).

Author	Year	Study Design	Sample	Relevant Findings
Bacic et al.	1989	Case-control	A random sample of 222 patients with diabetes was selected from a diabetes institute in Zagreb. Patients were referred from all parts of Croatia. The group with diabetes consisted of 109 patients with type 1 diabetes and 113 patients with type 1 diabetes. They had mean disease duration of 11 years. The mean age of the diabetes patients was 49.6 years. A control group of 189 controls was selected from the general population. The mean age of the controls was 43.9 years. All the participants were dentate.	The results obtained revealed no difference in the prevalence of caries between the group with diabetes and the control group. The DMFT score was slightly higher in the group with diabetes (17.7±6.9) than the group without diabetes (14.9±6.7) (p-value>0.05). The mean of missing teeth was higher among participants with diabetes (12.3±7.3) than those without diabetes (9.7±7.1) (p-value<0.01), but there were no significant differences in the decayed and filled teeth. Type 1 diabetes patients were found to have a significantly higher number of teeth with fillings than type 2 diabetes patients (4.1 vs. 2.2) (p-value<0.001). On the other hand, patients with type 2 diabetes, had a significantly higher number of extracted teeth compared to those with type 1 diabetes (14.1 vs. 10.4) (p-value<0.001). No correlation was found between DMFT score and the duration of disease, degree of diabetes control (MGB or HbA_{1c}) or diabetes complications (neuropathy and retinopathy). It is suggested that the intake of small amounts of carbohydrates several times a day, together with a high level of glucose in saliva, permits the presence of cariogenic bacteria and development of dental caries.

Author	Year	Study Design	Sample	Relevant Findings
Moore et al.	2001	Case-control	390 subjects were selected from an epidemiologic study from the University of Pittsburg. They were 1) dentate subjects, 2) with type 1 diabetes diagnosed during the years 1950-1980, 3) provided questionnaire data, 4) received a medical examination at baseline, and 5) underwent an oral examination in 1992-94. Their mean age was 32.6±0.4 years. 202 controls were spouses or friends of the participant with diabetes, or were recruited from the community through the newspaper. Their mean age was 33.0±0.5 years. The study group was primarily Non-Hispanic Whites (98.3%).	Subjects with diabetes had a higher DMFS score (33.7±1.2 vs. 26.2±1.7) compared to the controls (p-value<0.001). No significant differences were found in DFS between subjects with diabetes (21.7±0.8 vs. 19.1±1.2) compared to subjects without diabetes (p-value>0.05). Subjects with diabetes had significantly more missing teeth (2.51±0.8) compared to controls (1.44±0.28) (p-value<0.01). The prevalence of root caries was higher among the subjects with diabetes (16% vs. 8.4%) compared to the controls (p-value<0.01). Females with diabetes had a higher daily calories intake (2012 vs. 1821) (p-value=0.045) and had a higher meal frequency (5.4 vs. 4.5) (p-value<0.01) compared to female controls. Significant factors in the final linear regression model of DFS for subjects with diabetes were older age, female sex, frequent use of dental floss, more frequent visits to the dentist (last 12 months) and diabetic nephropathy. A significant interaction was found between nephropathy status and age in the model for decayed and filled surfaces (DFS). Overall differences in DFS scores for subjects with nephropathy were significantly greater than for subjects without nephropathy (28.4 vs. 19.8) (p-value<0.0001). A possible explanation is that patients with nephropathy continuously consume more fluids, possibly sugar-containing beverages throughout the day.

Author	Year	Study Design	Sample	Relevant Findings
Moore et al.	2001	Case-control	406 subjects were selected from an epidemiologic study from the University of Pittsburg. They had 1) type 1 diabetes diagnosed between the years of 1950-1980, 2) provided questionnaire data and a medical examination at baseline, and 3) underwent an oral exam in 1992-94. Their mean age was 33.1±0.4 years. 268 controls were recruited as spouses or friends of the participants with diabetes, or were recruited from the community through the newspaper. Their mean age was 31.8±0.5 years.	Declining salivary flow rates were seen with increasing fasting blood glucose levels among subjects with type 1 diabetes. Linear fit from a correlation test between salivary flow and blood glucose was the following: resting salivary flow rate= 0.309-0.00375 blood glucose (p-value<0.15) and for stimulated salivary flow rate = 1.120-0.00110 blood glucose (p-value<0.05). Subjects with type 1 diabetes were taking more prescription drugs (1.68±0.10 vs. 0.93±0.14) than the controls (p-value<0.001). Twice as many subjects with diabetes were taken drugs classified as *xerogenic* (7.6% vs. 3.7%) (p-value<0.05). The mean salivary flow rates (ml/min) were lower (resting: 0.22±0.01 vs. 0.28±0.02; p-value<0.005) and the prevalence of hyposalivation was higher (resting (<0.01 ml/min): 11.8% vs. 2.7%; p-value<0.0005 and stimulated (<0.10 ml/min): 12.4% vs. 5.5%; p-value=0.019) among the subjects with diabetes compared with the controls. Subjects with diabetes and minimal resting salivary flow rate were found to have a slightly higher prevalence of DFT (10.9±1.1 vs. 9.1±0.4) (p-value<0.05). It is suggested that hyposalivation and xerostomia were significant oral complications among patients with type 1 diabetes. The use of xerogenic medications significantly decreased salivary flow rates in both subjects with diabetes and controls.

Author	Year	Study Design	Sample	Relevant Findings
Twetman et al.	2002	Three-year follow-up study. To evaluate the caries incidence in a group of young patients during a three-year period from the onset of type1 diabetes.	Convenience sample of 64 children aged 8-16 years, who were referred for treatment of type 1 diabetes.	No difference of baseline caries prevalence was found according to metabolic control. On the three-year incidence of DFS and DS there were significant (p-value<0.05) difference in incidence among the children with less good metabolic control (HbA_{IC} >8.0%). In the three-year period the children with poorer metabolic control had a DS = 4.8 ± 7.8 and DFS = 5.4 ± 8.4, compared to children with good metabolic control DS = 1.4 ± 1.9 and DFS = 1.6 ± 2.0. Poor oral hygiene (visible plaque) (OR = 6.5), poorer metabolic control (OR = 5.7), caries experience at onset (OR = 5.3) and high levels of salivary lactobacilli (OR = 5.0) were statistically significant (p-value < 0.05) determinants for caries development.

Author	Year	Study Design	Sample	Relevant Findings
Ilgüy et al.	2007	Case-control	The study population had no concomitant diseases, not pregnant and not edentulous. The age range was 18-62 years. The study population consisted of 46 patients with type 1 diabetes (mean age 30.9 years, range of 18 to 70 years) and 40 patients with type 2 diabetes (mean age 43.1 years, range of 18 to 62 years). 50 healthy controls (mean age 30.6 years, range of 18 to 57 years) with no systemic disease or medications were selected.	The group with type 2 diabetes had less teeth (21.27±5.27) in comparison with those with type 1 diabetes (23.41±5.01) and controls (26.40±1.71) (p-value<0.001). The group with type 2 diabetes had a higher DMFS score (46.42±32.33) compared to type 1 diabetes (38.17±29.88) and the controls (21.64±29.36) (p-value<0.001). The group with type 2 diabetes also had more missing teeth surfaces (32.40±27.31) compared to type 1 diabetes (23.04±24.86) and controls (8.04±9.00) (p-value<0.001). No significant differences were found in decayed and filled teeth surfaces, when comparing participants with type 2 diabetes, type 1 diabetes and controls (p-value>0.05). No differences were found between males and females with regards to the number of teeth, prevalence of caries and restorations (p-value>0.05).

Author	Year	Study Design	Sample	Relevant Findings
Hintao et al.	2007	Cross-sectional	105 subjects with type 2 diabetes were recruited from an endocrine clinic at a hospital in Thailand. 103 subjects without diabetes were selected from the general practice clinic in the same hospital on their regular check-ups. They had no known history of diabetes and a fasting glucose level >110 mg/dl. Subjects without diabetes were matched by age and sex with the participants with type 2 diabetes.	The group with type 2 diabetes had less teeth present compared to those without diabetes (21.7±0.5 vs. 23.9±0.5) (p-value<0.01). Participants with diabetes had marginally higher mean of decayed and filled surfaces (DFS: 8.0±9.4 vs. 6.3±7.5) (p-value=0.09), but not significantly more decayed and filled teeth (DFS: 3.8±0.2 vs. 3.3±0.3) (p-value=0.25). The prevalence of coronal caries was marginally higher among participants with diabetes (83.8 vs. 72.8) (p-value=0.06). Participants with diabetes had a higher mean of root caries in surfaces (1.2±0.2 vs. 0.5±0.1) (p-value<0.001) and teeth (1.0±0.1 vs. 0.4±0.1) (p-value <0.01). The prevalence of root caries was also higher among participants with diabetes (40.0 vs. 18.5) (p<0.001) compared to those without diabetes. After adjusting, for all the independent variables, subjects with diabetes were independently of greater risk for root caries (OR=2.12; 95%CI: 1.08-4.14) but not for coronal caries (OR=1.08; 95%CI: 0.98-1.50) when compared to subjects without diabetes. Participants with diabetes had a higher percentage of generalized periodontitis (98.1 vs. 87.4) when compared to those without diabetes (p<0.01).

Author	Year	Study Design	Sample	Relevant Findings
				The group with diabetes had a higher oral hygiene index (OHI-S) (3.5±1.4 vs. 3.0±1.4) and plaque index (1.4±0.1 vs. 1.2±0.1) than the group without diabetes (p-value<0.05). The group with diabetes also had lower salivary flow rate (ml/min) (0.8±0.5 vs. 1.0±0.6) and salivary pH (7.6±0.5 vs. 7.8±0.4) compared to those without diabetes (p-value<0.05). There was no association between the coronal or root caries and duration of disease, poor diabetes control (HbA_{1c}>8.5%), diabetes complications and insulin treatment (p-value>0.05). It is suggested that periodontal disease and root surfaces caries prevention should be emphasized for subjects with type 2 diabetes.

Author	Year	Study Design	Sample	Relevant Findings
Soell et al.	2007	Review article	-	No consistent relationship between type 2 diabetes and increased prevalence of past caries in older adults. Salivary secretions are reduced in patients with diabetes. Increased caries in patients with poor controlled diabetes. Patients with diabetes have a predisposition to manifest oral diseases like candidiasis, which is associated with poor glycemic control and therapeutic dentures. This predisposition also contributes to xerostomia, which may be due to increased glucose level in oral fluid or immune dysregulation.

Author	Year	Study Design	Sample	Relevant Findings
Siudikiene et al.	2008	Case-control two-year follow-up study.	The 63 cases were 10-15 years old and registered in the Lithuanian Childhood Diabetes Register as having type 1 diabetes. The 68 controls were age- and sex matched with the cases. The mean age of the whole study group was 13.6±1.6 years. Oral exams were done at baseline and after two years.	No significant differences were found in total DMFS score between children with diabetes and controls at baseline (23.0±15.0 vs. 27.0±16.0), after 2 years (34.5±16.6 vs. 37.1±15.1) or new caries after 2 years (11.5±5.5 vs. 10.1±6.4) (p-value>0.05). No significant differences were found in active caries between children with diabetes and controls at baseline (11.1±9.9 vs. 13.5±14.4), after 2 years (12.9±8.9 vs. 13.4±9.4) or new caries after 2 years (1.8±6.9 vs. -0.1±9.4) (p-value>0.05). No significant differences were found in filled teeth surfaces between children with diabetes and controls at baseline (3.1±4.0 vs. 3.9±4.1), after 2 years (5.8±6.6 vs. 6.2±5.2) or new caries after 2 years (2.6±3.9 vs. 2.3±3.5) (p-value>0.05). No significant differences were found in extracted teeth between children with diabetes and controls at baseline (0.3±1.5 vs. 0.1±0.6), after 2 years (0.7±1.9 vs. 0.2±1.4) or new caries after 2 years (0.4±1.2 vs. 0.2±0.9) (p-value>0.05). Both unstimulated and stimulated salivary flow (ml/min) was always lower among children with diabetes compared to controls, at baseline (unstimulated: 0.27±0.2 vs. 0.35±0.2 and stimulated: 1.16±0.6 vs. 1.51±0.8) and remained lower after 2 years (unstimulated: 0.24±0.1 vs. 0.31±0.1 and stimulated: 1.31±0.5 vs. 1.61±0.5) (p-value<0.05). The salivary glucose was higher among children with diabetes compared to controls during the 2 years (baseline: 0.07±0.02 vs. 0.01±0.0 and 2-years: 0.14±0.3

Author	Year	Study Design	Sample	Relevant Findings
				vs. 0.04±0.1) (p-value<0.05). A worsening of oral hygiene was seen among participants with diabetes compared to controls. A higher increase after 2 years in the oral hygiene index (OHI-S) was seen among the children with diabetes (0.46±0.6 vs. 0.23±0.05) as well as the calculus index (CI-S) (0.22±0.4 vs. 0.09±0.2) (p-value<0.05). In the multivariate regression model using the whole sample (cases and controls) for DMFS increments the significant predictors were older age (β=0.66; p-value<0.001) and higher salivary glucose β=13.20; p-value<0.001). In the multivariate regression model, higher DMFS increments in children with diabetes compared to controls were associated with higher salivary glucose concentrations (β=3.01; p-value=0.029). In the multivariate regression model, higher DS increments among children with diabetes compared to controls were associated with more dental plaque (β= 8.47; p-value=0.004) and higher salivary albumin (β=0.05; p-value=0.01). Thus, dental plaque accumulation, increased salivary glucose concentration as well as changes in the biochemical composition of saliva in diabetic children seem to explain diabetes-related effects on the caries process.

CHAPTER 3: METHODS

3.1. Introduction

This chapter describes the methods of the study, including the research hypothesis, study aims, study design, data collection and statistical analysis used to evaluate the study aims.

3.2. Hypothesis

Elderly Puerto Ricans with diabetes residing in the San Juan Metropolitan Area will have a higher prevalence of coronal and root caries than elderly without diabetes.

3.3. Specific Aims

3.3.1. Aim 1

To evaluate differences in coronal caries experience among older adults with and without diabetes.

3.3.2. Aim 2

To estimate the magnitude of association between coronal caries and diabetes mellitus after adjusting for potential confounders.

3.3.3. Aim 3

To evaluate the prevalence of root caries in older adults with and without diabetes.

3.3.4. Aim 4

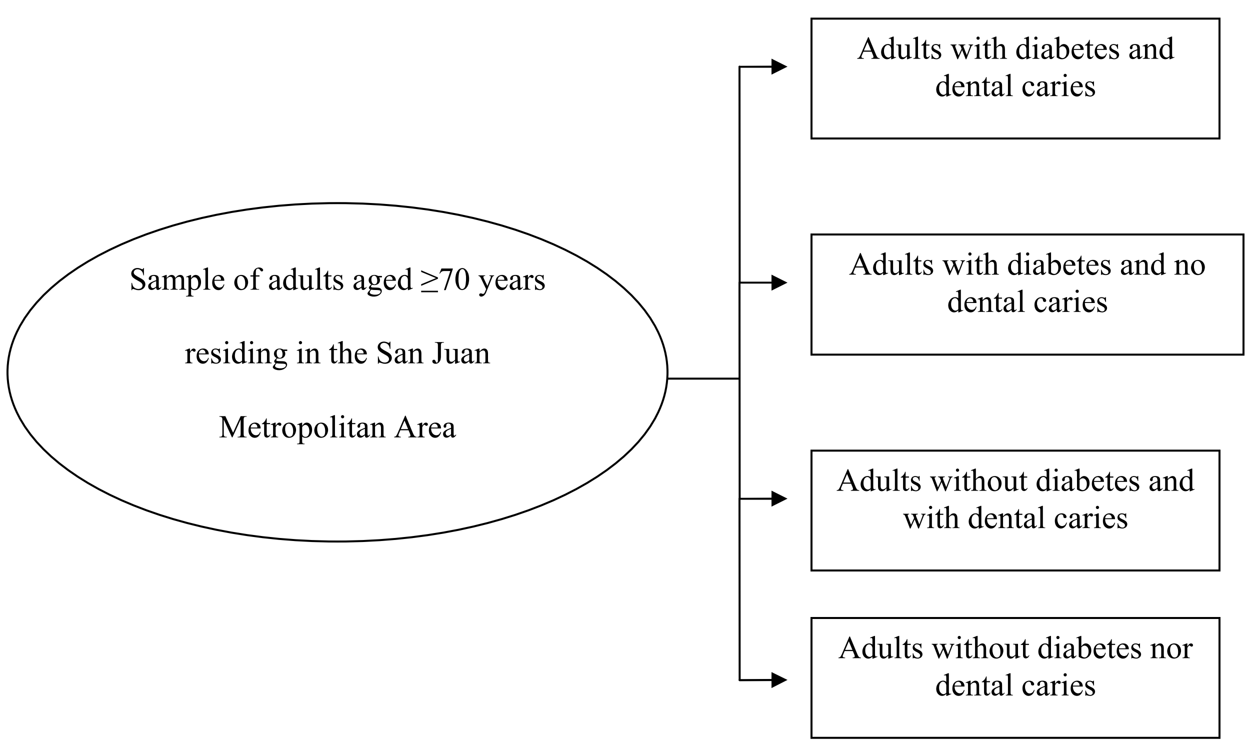
To estimate the magnitude of association between root caries and diabetes mellitus after adjusting for potential confounders.

3.4. Study design

The study design employed to evaluate the study aims was an analytical cross-sectional study based on a secondary data analysis. Cross-sectional studies are used to estimate the prevalence of disease or exposure in the population (Kelsey, 1986). They also enable investigations to estimate the magnitude of association between an exposure factor and a specific disease. Cross-sectional studies are most often carried out to learn about risk factors for diseases of slow onset and long duration for which medical care is often not sought until the disease has progressed to a relatively advanced stage (Kelsey, 1986). Cross-sectional studies have one major advantage over case-control studies in that they are often based on a sample of the general population so their generalizability is considered a strength (Kelsey, 1986).

However, cross-sectional studies suffer from two major limitations. As the exposure and disease are measured at the same time, it is not possible to determine the temporal sequence of the association. The other limitation is that there will be a higher proportion of prevalent cases than incident cases, as there will be more cases with diseases of long duration (Kelsey, 1986). This study assessed indices of dental caries in adults using a subsample of elderly Puerto Ricans with and without diabetes (Figure 3.1).

Figure 3.1. Study design based on a cross-sectional study



3.5. Study Group

The study group included adults aged 70 years and older residing in the San Juan Metropolitan Area that participated in the second phase of the study titled “Puerto Rican Elderly Health Conditions (PREHCO)” during 2005 and the “Puerto Rican Elderly Dental Study (PREDHS)” in 2007.

3.5.1. Inclusion criteria

The inclusion criteria for the PREDHS study were non-institutionalized adults aged 70 years and older residing in the San Juan metropolitan area. The subjects had to have at least one natural tooth retained for the assessment of the DMFT caries index.

3.5.2. Exclusion criteria

Exclusion criteria from the PREDHS study were the following:

1. Individuals previously identified for a future PREHCO clinical sub-study.
2. Individuals with no natural teeth at the time of interview
3. The following medical exclusions were made due to potential systemic complications arising from the periodontal exam:
    a) Individuals taking antibiotics required by a doctor prior to the oral examination performed by PREDHS.
    b) Individuals with a history of specific heart diseases (congenital heart murmurs, valve problems, congenital heart disease, endocarditis or rheumatic fever)
    c) Individuals undergoing dialysis treatment
    d) Individuals with a pacemaker or automatic defibrillator of artificial material in heart or vessels
    e) Individuals on anticoagulant medication or diagnosed with hemophilia

f) Individuals who had undergone hipbone or joint replacement surgery

3.6. Data Sources

This study was based on a secondary data analysis from the studies of PREHCO and PREDHS. To better understand the databases, it is important to describe the sampling design.

3.6.1. PREHCO

The PREHCO project was designed to evaluate the health, behavioral status and needs of older adults aged 60 years and older in Puerto Rico. A comprehensive questionnaire was designed to gather information on socio-economic factors, social support, self-report of health status and medical conditions, cognitive and functional performance, anthropometric measurements and physical performance, childhood characteristics and health care utilization. It was sponsored by the National Institute of Health (NIH) and was conducted as a joint collaboration of the Graduate School of Public Health at the Medical Sciences Campus of the University of Puerto Rico and the Center for Demography and Ecology of the University of Wisconsin-Madison (Palloni et al., 2003).

The PREHCO project was an ongoing cohort study of the non-institutionalized population aged 60 years and older and their surviving spouses in Puerto Rico, excluding the municipalities of Culebra and Vieques. The sample was selected using a multistage, stratified design of the elderly population residing in Puerto Rico with over-sampling of regions heavily populated by people of African descent and of individuals aged over 80. The first stage of sampling was the random selection of groups of household blocks based on the Census 2000. The second stage consisted of the random selection of sections created by the union or division of household blocks, in order to reach an average of 90 households per division. The third stage consisted of the random selection of households with an adult 60 years and older; and in the final stage all adults 60 years and older who lived in that household were selected. The probability of selection in the first (groups of blocks) and the second (sections) stages was proportional to the size, according to the total of households reported in the Census 2000. The data was collected by in-home interviews. The total sample consisted of 5,336 participants, and 55.7% were females (Palloni et al., 2003).

3.6.2. PREDHS

The PREDHS study was designed to assess the oral health status of a representative sub-sample of elders living in the San Juan Metropolitan Area defined by census blocks that included the eight municipalities that have 009 as the first three digits in their area code. The study was conducted between July and October 2007. The PREHCO study served as the parent study to the PREDHS by providing the sampling frame and some of the information of the participants needed in this study. All the participants in the strata of San Juan (n=1,364) were selected, and the initial inclusion criteria for the PREDHS study were applied. These criteria included participants that were 70 years and older, participants in the second wave of PREHCO, residents of the San Juan metropolitan area, passed the Caban mini-mental test and not being invited to participate in the PREHCO concurrent clinical study. After excluding participants who did not meet the initial inclusion criteria, 392 potentially eligible participants were contacted regarding the PREDHS study. The initial contact was made by phone (when available), by mail or by knocking at potential participants' doors. A number of 23 participants were never reached, 107 refused to participate and 19 were sick, dead or hospitalized. Additional medical exclusion criteria, specific to the PREDHS study, were verified upon contact with the potential participants. A group of 58 participants were excluded due to medical criteria, and one person did not complete the oral health exam. The final sample of the PREDHS study comprised of 184 subjects.

Home visits were scheduled with all but one participant, who preferred to be evaluated at the UPR School of Dental Medicine. Three teams, consisting of one clinician and one recorder/interviewer, conducted the dental exams, indirect blood pressure measurements and personal interviews. The clinicians were trained and standardized by the NHANES standard examiner, Dr. Bruce A. Dye. Personal interviews were made to collect self-reported information on periodontal disease, hygiene practices, use of dental health services, denture conditions, hypertension and diet. Complete oral exams were conducted to assess tooth loss, coronal and root caries, periodontal disease, tooth mobility, denture conditions and prosthetic needs (Joshipura et al., unpublished data).

3.7. Study Variables

3.7.1. Outcomes

3.7.1.1. Coronal caries

Coronal caries was summarized using the DMFS index, which indicates the life experience of dental caries of a person. Presence of coronal caries was measured by the DMFS index whose components are: number of decayed (D), number of filled (F) and number of missing (M) surfaces. Every component can be analyzed separately, and the DMFS index is a sum of its components. As the third molars are excluded, the DMFS index ranges from 0 to 128. Missing surfaces were considered only if they were due to disease, dental caries or periodontal disease. A DMFS score of zero indicates that the person has no decayed, filled or missing teeth surfaces, whereas a DMFS score of 128 implies all the teeth surfaces are affected. The DMFS index is described below:

- D component indicates the number of decayed surfaces (0-128)
- M component indicates the number of missing surfaces (0-128)
- F component indicates the number of restored surfaces (0-128)

3.7.1.2. Root caries

The presence of root caries was defined as one or more teeth with root caries, and the presence of root restorations as one or more teeth with root restorations.

3.7.2. Exposure

3.7.2.1. Diabetes

Presence of diabetes was based on the answer, to the following question: Has a doctor ever told you have diabetes or that your blood sugar levels are high?

3.7.3. Potential confounding variables

3.7.3.1. Age

It is a continuous variable based on the following open question: How old are you?

3.7.3.2. Sex

It is a categorical nominal variable that defines the participant's sex and was categorized:

1 – Male

2 - Female

3.7.3.3. Monthly family income

This variable indicates the monthly family income and was categorized as follows:

- Would you say that the monthly income of the home is more than $3,000?
- Would you say that the monthly income of the home is more than $2,000?
- Would you say that the monthly income of the home is more than $1,500?
- Would you say that the monthly income of the home is more than $1,000?

- Would you say that the monthly income of the home is more than $500?

3.7.3.4. Medical insurance

This variable is an indicator of access to health care and was defined based on the following questions:

- Do you have a medical insurance?
- What type of medical insurance do you have?

1 – Government administered health insurance

2 – Medicare (A - hospitalization, B - ambulatory services and D - medications)

3 – Other: private insurance (Triple S, Cruz Azul, Humana) and particular organizations (teacher, police, federal employee, veteran).

3.7.4. Behavioral variables

3.7.4.1. Physical activity

This variable indicates if the participant performed any physical activity during the last year and was based on the following question:

- During the last year, did you practice any of the following activities: sports, jogging, walk, dance, or heavy work, three or more times a week?

3.7.4.2. Visits to the dentist

This variable indicates if the participant visited the dentist in the last year and was based on the following question:

- During the last 12 months, did you visit the dentist?

3.7.4.3. Hygiene practices

Hygiene practices were measured by the use of mouthwash, dental floss or interdental toothbrush during the last seven days, based on the following questions.

- During the past seven days, how many times did you use a mouthwash or other dental liquid?
- During the past seven days, how many times did you use a dental floss or interdental toothbrush?

3.7.4.4. Oral health indicator

An oral health indicator was created combining the three variables related to oral health; visit to the dentist, use of mouthwash and dental floss according the following categories that indicates how many of the oral health related practices were completed by the participants:

- None (0)
- Any (1 or 2)
- All (3)

3.7.4.5. Food intake

Consumption of proteins and fibers was measured by the intake of plantains, fruits, potatoes, vegetables, breads and cereals, based on the following questions:

- How many portions of plantains/fruits/vegetables do you consume during a week?
- How many portions of wheat breads/cereals do you consume during a week?

3.7.4.6. Difficulty to chew

This categorical variable is an indicator of any difficulties to chew and was based on the following question:

- During this last year, have you had any difficulties to chew?

3.7.4.7. Obesity

Body mass index (BMI), a measure for relative weight, was calculated as weight (kg) divided by squared height (m) at the time of interview of PREHCO.

3.7.4.8. Alcohol consumption

This variable indicates if the subjects consume any alcohol. This is a categorical variable based on the following question:

- During the last three months, did you consume alcoholic beverages (for example, beer, wine, rum or other beverages that contain alcohol)?

3.8. Data processing

The data from PREHCO and PREHDS were merged using the identification number assigned to the participants.

3.9. Statistical analysis

A description of the study groups was performed using summary statistics such as means, medians, standard deviations and first and third quartiles (Q_1, Q_3). Then, a bivariate analysis was performed to compare the mean of dental caries indices across diabetes status using Student's t-test and analysis of variance. An assessment of the magnitude of association between dental caries (coronal and root caries) and diabetes was performed using linear or logistic regression models. Finally, the magnitude of association between dental caries and diabetes adjusted by potential confounder variables was estimated using multiple linear or logistic regression models. All the statistical analysis were performed with Stata version 10.0 (Stata Corporation, College Station, Texas).

3.9.1. Univariate analysis

Prevalence of diabetes was computed using the following equation:

$$\hat{p} = \frac{x}{n}$$

where:

$\hat{p}$ = prevalence of diabetes

x = number subjects with diabetes

n = total sample

The same procedure was applied for different categorical variables, such as socio-demographic, anthropometric, lifestyle, dietary and oral hygiene variables. For quantitative variables, measures of central tendency and dispersion were computed (mean, median, quartiles, standard deviation) (Rosner, 2006).

3.9.2. Bivariate Analysis

3.9.2.1. Diabetes status

To identify variables that could be associated with diabetes status, a simple logistic regression model was performed using the following equation:

$$\text{logit}(p) = \beta_0 + \beta_1 x$$

where:

logit (p) = logit function that indicates ln [p/(1-p)]

p = prevalence of diabetes

β_0 = intercept of logit function

β_1 = regression coefficient associated with the independent variable

x = exposure or potential confounding variable

To estimate the magnitude of association between diabetes status with different variables, the prevalence odds ratio (POR) was estimated with 95% confidence interval (95% CI) based on the logistic regression model, as follows:

$$\text{Estimated POR} = e^{\hat{\beta}_1 \pm 1.96 * S\hat{E}(\hat{\beta}_1)}$$

where:

$S\hat{E}(\hat{\beta}_1)$ = indicates the standard error of the coefficient $(\hat{\beta}_1)$

Based on the simple logistic regression model an operational criterion of POR≥1.50 was used to identify the variables clinically important to be considered for inclusion in the multivariate analysis, in addition to significant association with caries outcome and clinical significance.

3.9.2.2. Coronal caries

To compare the average DMFS score in adults with and without diabetes, a Student's t test was performed if statistical assumptions were met. Homogeneity of variances was formally assessed by Bartlett's test. If the variances of DMFS score were not homogeneous between groups after the log-transformation, then the Wilcoxon-Mann-Whitney test was used to compare the median scores in the two groups. In order to evaluate the mean DMFS index across socio-demographic variables with more than two groups, ANOVA was used. If the assumption of homogeneity of variances was not satisfied using Bartlett's test, then the Kruskal-Wallis test was used. In order to find a model that better fitted our data, three regression models were evaluated. When the outcome variable was DMFS, the linear regression model was used. For the discrete variables DS and FS without evidence of overdispersion, the Poisson regression model was used, but if the overdispersion was high then the negative binomial model was used. To evaluate high overdispersion in the Poisson regression model, the Langrange test and Z-test were used (Hoffman, 2004). For the variable MS a logistic regression model was used.

3.9.2.2.1. DMFS

As the DMFS index is a quantitative and discrete variable, a linear regression model was used to assess the mean DMFS index using different predictive variables, as follows:

$$E(Y) = \beta_0 + \beta_i x_i$$

where:

Y= DMFS index

β_i = regression coefficient associated with the exposure or potential confounding variable

x_i = exposure or potential confounding variables

3.9.2.2.2. DS and FS

Many outcomes in clinical research and epidemiological studies are finite discrete data of non-negative values that are not normally distributed. The linear regression model assumes that the errors are independent and identically normally distributed with a mean of zero. Transformation of the data can be applied to meet the assumption of normal distribution; however, if the data is very skewed; for example, when many participants have zero caries, then the mathematical transformations were not sufficient and other alternative models were explored. The Poisson regression can be used when the data is not normal and has many individuals without caries (DMFS=0), which makes the data right skewed.

The functional form of the Poisson regression model is given by:

$$\log(\mu_i) = \beta_0 + \beta_1 x_{1i}$$

where:

μ_i = indicates the expected value of the outcome variable Y_i under the i^{th} condition

x_{1i} = indicates the exposure or potential confounding variable with corresponding regression coefficient β_1.

The outcome variable of the Poisson regression model assumes a Poisson distribution where the expected value is equal to the variance: E(Y) = Var(Y). When this assumption is not met, overdispersion or underdispersion could occur in the parameter estimation of the Poisson model (Hoffman 2004).

An alternative for the Poisson regression model to analyze discrete data is the negative binomial regression model. It is a generalization of the Poisson regression model that accounts for overdispersion by including a disturbance or error term in the model (Hilbe, 2007). The usual functional form of the negative binomial regression model is given by:

$$\log(\lambda_i) = \beta_0 + \beta_i x_i$$

where:

λ_i = indicates the expected value of the outcome variable Y_i under the i^{th} condition

x_i = indicates the exposure or potential confounding variable with corresponding regression coefficient β_i

The outcome variable in a negative binomial regression model assumes a negative binomial distribution. Under this distribution, the expected value is less than the variance (E(Y) < Var(Y)). Although this model has not been widely used, some studies prefer this model when analyzing discrete data with a high frequency of outcomes with zeros values (Byers et al., 2003)

In the Poisson regression model the difference of DS and FS according to diabetes status was assessed with the relative difference (RD), which is the ratio of the mean DS (or FS) in the group with diabetes divided by the mean in the group without diabetes, as follows:

$$RD = \frac{\mu_1}{\mu_2}$$

where:

μ_1 = is the mean DS or FS among participants with diabetes

μ_2 = is the mean DS or FS among participants without diabetes

Therefore, the statistical hypothesis to assess the mean DS and FS across diabetes status was the following:

$$H_0: \mu_1 / \mu_2 = 1.0$$

$$H_a: \mu_1 / \mu_2 \neq 1.0$$

The p-value and 95% confidence interval were used to assess significance.

3.9.2.2.3. MS

To evaluate the association between missing surfaces (MS) and diabetes status, a logistic regression was used because the distribution of the aggregate values of this variable was better explained by the binomial distribution. Therefore, the variable was dichotomized according to MS values at or below and above the median (≤50 vs. >50 surfaces). The functional form of the logistic model is given by:

$$\text{logit}(p) = \beta_0 + \beta_1 x_{1i}$$

where:

logit (p) = logit function that indicates ln [p/(1-p)]

p = indicates the prevalence of participants with values of missing surfaces above the median

x_{1i} = indicates the self-reported status of diabetes

β_1 = indicates the regression coefficient associated with the variable x

β_0 = indicates the intercept of the logit function

The estimated POR with its 95% confidence interval (95% CI) were determined to assess the magnitude of association between MS and diabetes status as follows:

$$\text{estimated POR} = e^{\hat{\beta}_1 \pm 1.96 * S\hat{E}(\hat{\beta}_1)}$$

where:

$S\hat{E}(\hat{\beta}_1)$ = indicates the standard error of the coefficient $(\hat{\beta}_1)$ associated to x_i with values of missing surfaces above the median

3.9.2.3. Root Caries

To describe the association between root caries and diabetes, the following table was used (Hosmer, 2000):

Diabetes	**Root Caries**		**Total**
	+	-	
+	**a**	**B**	**a+b**
-	**c**	**D**	**c+d**
Total	**a+c**	**b+d**	**n = a+b+c+d**

where:

a= number of subjects with diabetes and root caries

b= number of subjects with diabetes and no root caries

c= number of subjects without diabetes and with root caries

d= number of subjects without diabetes nor root caries

n = total number of subjects in the study

To quantify the magnitude of association between the prevalence of root caries and diabetes status, the prevalence odds ratio (POR) was estimated using the logistic regression model.

3.9.3. Multivariate Analysis

To define the inclusion criteria to enter the multiple regression model, assessment of each predictor was performed using a simple regression model. Predictor variables with a p-value less than 0.05 were considered for inclusion in the multiple linear regression model. Another criteria for including predictor variables in a multivariate model was to satisfy the criteria of POR≥1.50 with diabetes as an outcome variable. The variables of age and sex were always included in the model because of their clinical importance in both dental caries and diabetes. An assessment of first-order interaction terms in the multiple linear regression model was evaluated using the Likelihood-ratio test. In order to evaluate interaction between diabetes and other variables included in the multivariate model, the number of participants in each cell had to be five or more in a contingency table between diabetes and sex for different strata. If a significant interaction between the predictor variables were found, the interaction term was added to the multiple regression model to estimate the magnitude of association between dental caries and diabetes among different subgroups.

3.9.3.1. Coronal Caries indices

3.9.3.1.1. DMFS

The magnitude of association between DMFS and diabetes status adjusted by other potential confounding variables was evaluated using a multiple linear regression model, as follows (Rosner, 2006):

$$E(Y) = \beta_0 + \beta_1 x_{1i} + \ldots + \beta_k x_{ki}$$

where:

Y= DMFS index

x_i = indicates the independent variables, including diabetes status, potential confounding variables, and first-order interaction terms.

β_i = regression coefficients associated to independent variable x_i

The previous described strategy to define the inclusion criteria to enter a multiple regression model was applied to the multivariate model to explain DMFS. Being unique to this model that the individual assessment of each predictor was performed using a simple linear regression model (SLRM) and predictor variables with a p-value less than 0.05 in the SLRM were considered for inclusion in the multiple linear regression model.

3.9.3.1.2. DS and FS

For the discrete variables DS and FS the model that best suited our data was used in the multivariate regression model. If there was evidence of overdispersion, the Poisson regression model was used:

$$\log (\mu_i) = \beta_0 + \beta_1 x_{i1} + \beta_2 x_{i2} + \ldots + \beta_k x_{ik}$$

where:

μ_i = indicates the expected value of the outcome variable Y for the i^{th} condition

x_i = indicates the independent variables with corresponding regression coefficients β_i.

But if the overdispersion was high, then the following negative binomial model was used:

$$\log \lambda_i = \beta_0 + \beta_1 x_{i1} + \beta_2 x_{i2} + \ldots + \beta_k x_{ik} + \sigma\varepsilon_i$$

where:

λ_i = indicates the expected value of the outcome variable Y for the i^{th} condition

x_i = indicates the independent variables with corresponding regression coefficients β_k

$\sigma\varepsilon_i$ = indicates the disturbance term

For the models to explain DS and FS the same strategy to define the criteria to include variables in the multivariate model was applied. In these models the individual assessment of each predictor was performed using a simple Poisson regression model and the predictors with a p-value less than 0.05 in the simple Poisson regression model were considered for inclusion in the multivariate Poisson regression model.

3.9.3.1.3. MS

For the discrete variable MS, a multiple logistic regression model was used to evaluate the magnitude of association between MS and diabetes, adjusted for confounding variables:

$$\text{logit}(p) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_k x_k$$

where:

p = indicates the prevalence of participants with missing surfaces above the median

x_i = indicates the independent variables, which includes status of diabetes, potential cofounding variables, and first-order interaction terms

β_i = indicates the regression coefficient associated to x_i

For the models to explain MS the same strategy to define the criteria to include variables in the multivariate model was applied. Differently to previous models, the individual assessment of each predictor was performed using a simple logistic regression model and the predictors with a p-value less than 0.05 were considered for inclusion in the multivariate logistic regression model.

3.9.3.2. Root caries

The magnitude of association between root caries and diabetes adjusted for confounding variables was evaluated using a multiple logistic regression model:

$$\text{logit}(p) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_k x_k$$

where:

p = indicates the prevalence of participants with root caries

x_i = indicates the independent variables, which includes status of diabetes, potential confounding variables, and first-order interaction terms

β_i = indicates the regression coefficient associated to x_i

The same strategy to define the criteria for inclusion of variables in the multivariate model was applied. The individual assessment of each predictor was performed using a simple logistic regression model. The predictors with a p-value less than 0.05 in this model were considered for inclusion in the multiple logistic regression model.

CHAPTER 4: RESULTS

4.1. Introduction

This chapter summarizes the results of the analysis to evaluate the association between DMFS indices and root caries with diabetes. First, the study group was described in terms of each study variable. Then, a comparison analysis was performed to determine if the mean DMFS indices and root caries varied according to the diabetes status of the participants. Finally, multivariate regression models were used to explain the different indices as a function of diabetes status adjusting for potential confounding variables.

4.2. Univariate Analysis

4.2.1. Comparison of PREDHS participants and non-participants

The people who refused to participate in the PREDHS study were compared with the participants in terms of socio-demographic and lifestyle variables. Oral health data was not available for the people who refused and could therefore not be assessed. The demographic profile of the two groups was similar; however, there were significant differences in the distribution of the two groups by sex and insurance type. Among non-participants, there was a higher proportion of females (80% vs. 67%; p-value<0.05) and alcohol consumption (86% vs. 77%; p-value<0.05) (Table 4.1).

Table 4.1. Comparison of PREDHS participants and non-participants

	Participants (n=184)	Non-participants (n=107)	Total (n=291)
Sex*			
Male	61 (33.2)	21 (20.6)	80 (28.7)
Female	123 (66.5)	74 (79.4)	197 (71.3)
Age (years)			
≤ 78	100 (54.4)	48 (47.1)	148 (51.8)
> 78	84 (45.7)	54 (52.9)	138 (48.3)
Education in years			
≤ 12	99 (54.1)	52 (51.0)	151 (53.0)
> 12	84 (45.9)	50 (49.0)	134 (47.0)
Monthly family income			
Less than $1000	80 (44.0)	47 (49.0)	127 (45.7)
$1000 or more	102 (56.0)	49 (51.0)	151 (54.3)
Type of insurance			
Government-sponsored (only)	14 (7.7)	2 (2.0)	16 (5.7)
Medicare (A, B & D)	85 (46.7)	57 (56.4)	142 (50.2)
Private insurance and other	83 (45.6)	42 (41.6)	125 (44.2)
BMI (kg/m^2)			
Normal (<25.0)	60 (34.5)	28 (30.4)	88 (33.1)
Overweight (25.0-29.9)	72 (41.4)	41 (44.6)	113 (42.5)
Obese (≥30.0)	42 (24.1)	23 (25.0)	65 (24.4)
Smoking status			
Never	135 (73.4)	71 (69.6)	206 (72.0)
Ex-smokers and current	49 (26.6)	27 (30.4)	80 (28.0)
Alcohol consumption during the last 30 days*			
Yes	140 (76.5)	88 (86.3)	228 (80.0)
No	43 (23.5)	14 (13.7)	57 (20.0)
Diabetes status			
Yes	51 (27.7)	27 (26.0)	78 (27.1)
No	133 (72.3)	77 (74.0)	210 (72.9)

* Chi-square or Fisher exact test, p-value<0.05

4.2.2. Description of study group

The study group comprised 184 subjects, of which, 28% self-reported a medical diagnosis of diabetes. More than two-thirds (67%) were females, and the mean age was 78.6 ± 5.9 years. Almost 46% of the subject had achieved more than high school education, and 57.1% had a monthly family income of at least $1,000. Only 8% had solely the government's health insurance, while 46.7% had Medicare A, B or D which could be combined with the government's health insurance. Around two-thirds of the participants were overweight or obese (BMI>25.0 kg/m^2) (Table 4.2).

Table 4.2. Description of socio-demographic and anthropometric variables, n =184*

	Participants	**%**
Diabetes		
Yes	51	27.7
No	133	72.3
Sex		
Male	61	33.2
Female	123	66.8
Age in years		
≤ 78	100	54.4
> 78	84	45.6
mean ± SD (years)	78.6 ± 5.93	
Education in years		
≤ 12	99	54.1
> 12	84	45.9
mean ± SD (years)	10.86 ± 4.33	
Monthly family income		
< $1,000	78	42.9
≥ $1,000	104	57.1
mean ± SD ($)	$1,527 ± 1,199	
Health insurance type		
Government-sponsored (only)	14	7.7
Medicare (A, B &D)	85	46.7
Private insurance	83	45.6
BMI (kg/m^2)		
Normal weight (≤ 25.0)	62	33.9
Overweight (25.0 – 29.9)	75	41.0
Obese (≥ 30.0)	46	25.1
mean ± SD (kg/m^2)	27.35 ± 5.33	

* Variations in number are due to missing values

Most of the participants (94.6%) reported no smoking or alcohol consumption during the last 3 months (76.5%). More than half of the participants (62.9%) reported physical activity during the last 30 days, although less people indicated participation in a structured exercise or routine for exercise during the last 30 days (30.9%). A third of the participants (32.6%) reported eating 3 or more daily portions of fruits and vegetables, and

43.3% reported consuming 7 or more weekly portions of wheat bread or cereals (Table 4.3).

Table 4.3. Description of diabetes status and lifestyles characteristics, n=184*

	Participants	**%**
Diabetes		
Yes	51	27.7
No	133	72.3
Smoking status		
Current smoker	10	5.4
Ex-smoker	39	21.2
Never	135	73.4
Alcohol consumption during the last 3 months		
No	140	76.5
Yes	43	23.5
Exercise during the last 30 days		
No	66	37.1
Yes	112	62.9
Structured exercise		
No	123	69.1
Yes	55	30.9
Fruits or vegetable consumption during the last 7 days		
< 3 portions (daily)	118	67.4
≥ 3 portions (daily)	57	32.6
Wheat bread/cereals consumption during the last 7 days		
< 7 portions (weekly)	102	56.7
≥ 7 portions (weekly)	78	43.3

* Variations in number are due to missing values

Approximately 65.6% of the participants had visited the dentist at least once during the last 12 months and reported the use of dental floss at least once a week. However, more than half (52.7%) reported not using mouthwash as part of their daily oral health routine. Some responders indicated difficulty to chew (17.9%) (Table 4.4).

Table 4.4. Description of variables related to oral hygiene, n=184*

	Participants	%
Visited the dentist during the last 12 months		
No	63	34.4
Yes	120	65.6
Use of mouthwash/dental rinse in the last 7 days		
No	97	52.7
Yes	87	47.3
Use of dental floss/interdental brush in the last 7 days		
No	64	34.8
Yes	120	65.2
Oral health indicator†		
None	22	12.0
Any	107	58.5
All	54	29.5
Difficulty to chew		
No	151	82.1
Yes	33	17.9

†Participants who visited the dentist during the last 12 months, used mouthwash and/or dental floss during the last 7 days

*Variations in number are due to missing values

4.2.3. Description of DMFS

Figure 4.1 shows the overall distribution of the DMFS in the study group, whereas Figures 4.2-4.4 show the distribution of the individual DMFS components.

Evaluation of the normality assumption showed that the overall DMFS index met this assumption (p-value>0.05), while the individual components did not (p-value<0.001). Both DS and FS indices had positive asymmetric distributions with 53% of the DS data and 17% of the FS data equal to zero (Figures 4.2 & 4.4, respectively). The distribution of MS had a slight positive asymmetry, with 1% of the data equal to zero and more than half of the data (51%) less than 50 missed surfaces (Figure 4.3). After employing several mathematical transformations to the distribution of decayed, filled or missing surfaces, normality was not achieved. Therefore, Poisson distribution was assumed for DS and FS indices whereas a binomial distribution was employed for MS.

The Poisson and logistic regression models were used to assess the effect of different factors on the expected value of these indices.

Figure 4.1. Distribution of decayed, missing and filled surfaces (DMFS)

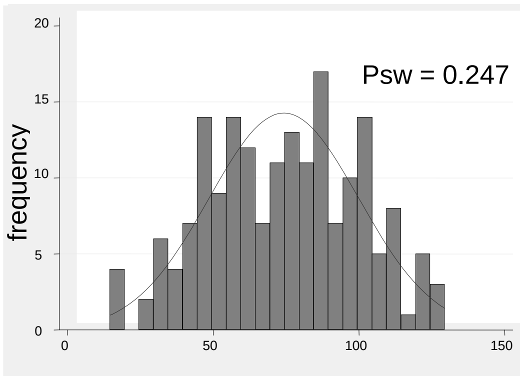


Figure 4.2. Distribution of decayed surfaces (DS)

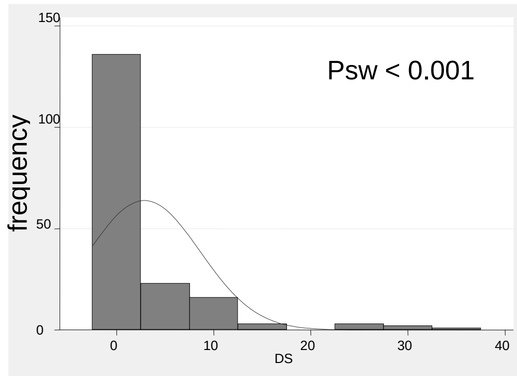


Figure 4.3. Distribution of missing surfaces (MS)

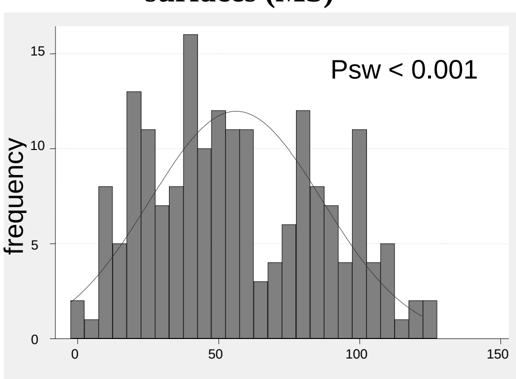
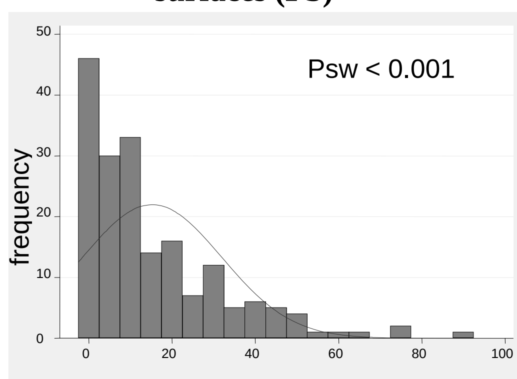


Figure 4.4. Distribution of filled surfaces (FS)



P_{sw} = p-value from Shapiro-Wilk test to assess normality assumption

4.3. Bivariate Analysis

4.3.1. DMFS by diabetes status

Our findings showed no significant differences in the average DMFS index between subjects with and without diabetes (p-value>0.10). Participants with diabetes had non-significantly more decayed and missing surfaces compared to participants without diabetes (p-value>0.10). However, the group with diabetes had significantly less restored teeth surfaces (FS) (p-value<0.05) compared with the group without diabetes (Table 4.5). This analysis was also done with the DMFT index, and the results were similar (results not shown).

Table 4.5 DMFS indices by diabetes status, n=184

Index	Statistics	Diabetes		Total (n=184)
		Yes (n=51)	No (n=133)	
DMFS	Mean ± SD	76.5 ± 26.0	73.4 ± 25.6	74.3 ± 25.7
	Median	79	75	75.5
	Q_1	57	52	54
	Q_3	96	93	94.5
DS	Mean ± SD	4.3 ± 7.9	2.3 ± 4.6	2.9 ± 5.7
	Median	0	0	0
	Q_1	0	0	0
	Q_3	7	2	3
MS	Mean ± SD	61.7 ± 30.2	54.1 ± 30.7	56.2 ± 30.7
	Median	60	49	50.5
	Q_1	40	25	30
	Q_3	86	79	81
FS*	Mean ± SD	10.5 ± 11.7	17.0 ± 18.0	15.2 ± 16.7
	Median*	8	10	9.5
	Q_1	1	4	2.5
	Q_3	16	27	21.5

* Mann-Whitney test, p-value<0.05

The results showed similar trends when the analysis was performed by age subgroups. Among participants 78 years and younger, those with diabetes had non-significantly more decayed surfaces but less restored surfaces compared to participants without diabetes (p-value>0.10). No differences were seen in the DMFS index or missing surfaces across diabetes status (p-value>0.10) in this age group (Table 4.6a).

Table 4.6a DMFS indices by diabetes status among participants aged ≤ 78 years, n=100

Index	Statistics	Diabetes		Total (n=100)
		Yes (n=29)	No (n=71)	
DMFS	Mean ± SD	75.6 ± 23.8	68.5 ±25.0	70.6 ± 24.8
	Median	74	68	70.5
	Q_1	58	49	50
	Q_3	97	89	90.5
DS	Mean ± SD	3.4 ± 7.1	1.87 ± 3.4	2.32 ± 4.8
	Median	0	0	0
	Q_1	0	0	0
	Q_3	2	2	2
MS	Mean ± SD	59.7 ± 29.0	51.0 ± 28.7	59.3 ± 32.5
	Median	60	45	56
	Q_1	40	25	36.5
	Q_3	84	78	84
FS	Mean ± SD	12.5 ± 12.2	15.6 ± 16.4	14.7 ± 15.3
	Median	10	10	10
	Q_1	1	4	4
	Q_3	17	23	20.5

Among the participants over 78 years old, non-significantly more decayed and missing surfaces were seen among the participants with diabetes. Consistent with results seen in the other age group, the participants with diabetes had significantly less restored surfaces when compared with those without diabetes (p-value<0.05). No differences were seen in the DMFS index across diabetes status (p-value>0.10) (Table 4.6b).

Table 4.6b DMFS indices by diabetes status among participants with age > 78 years, n=84

Index	Statistics	Diabetes		Total
		Yes (n=22)	No (n=62)	(n=84)
DMFS	Mean ± SD	77.5 ± 29.3	79.1 ± 25.4	78.7 ± 26.3
	Median	83.5	82.5	83
	Q_1	57	62	60.5
	Q_3	94	98	95
DS	Mean ± SD	5.4 ± 9.0	2.8 ± 5.6	3.5 ± 6.7
	Median	1.5	1	1
	Q_1	0	0	0
	Q_3	7	3	3.5
MS	Mean ± SD	64.3 ± 32.2	57.6 ± 32.7	59.4 ± 32.5
	Median	59.5	53.5	56
	Q_1	40	30	36.5
	Q_3	88	81	84
FS*	Mean ± SD	7.8 ±10.7	18.7 ± 19.7	15.8 ± 18.3
	Median*	5	10.5	9
	Q_1	0	3	1.5
	Q_3	11	28	26

* Mann-Whitney test, p-value<0.05

4.3.2. Distribution of root caries and root restorations by diabetes status

No significant differences were seen in root caries or root restorations between people with and without diabetes (p-value>0.05), thus no further analysis were made (Table 4.7).

Table 4.7. Root caries and root restorations by diabetes status, n=183

	Diabetes		P-value
	Yes	No	
Root caries	n (%)	n (%)	
Yes	24 (47.1)	60 (45.5)	$p_{\chi^2\text{- test}} > 0.10$
No	27 (52.9)	72 (54.4)	
Root restorations			
Yes	23 (45.1)	72 (54.5)	
No	28 (54.9)	60 (45.5)	$p_{\chi^2\text{- test}} > 0.10$

4.3.3. DMFS by demographic, lifestyle and oral health characteristics

DMFS index was significantly higher (p=0.03) among older individuals; however, this index did not differ according to sex, education, family income or health insurance type (Table 4.8).

Table 4.8. Average DMFS by demographic characteristics*

	DMFS (SD)	p-value
Sex		
Male	76.0 (25.1)	> 0.10
Female	73.4 (26.1)	
Age in years		
≤ 78	70.6 (24.8)	0.03
> 78	78.7 (26.3)	
Education in years		
≤ 12	73.9 (25.5)	> 0.10
> 12	74.7 (26.3)	
Monthly family income		
Less than $1000	72.8 (28.1)	> 0.10
$1000 or more	75.4 (24.0)	
Type of insurance		
Government-sponsored (only)	72.7 (26.9)	> 0.10
Medicare (A, B &D)	74.2 (25.1)	
Private insurance	74.3 (25.7)	

* Student t-test or one-way ANOVA when more than two categories

People who reported exercising routine had a significantly higher index of DMFS (p-value<0.05). DMFS index did not vary according to BMI, smoking status, alcohol consumption, exercise during the last 30 days or dietary intake variables (p-value>0.05) (Table 4.9).

Table 4.9. Average of DMFS by lifestyle and dietary variables*

	DMFS (SD)	p-value
BMI (kg/m^2)		
< 25.0	70.6 (26.3)	> 0.10
≥ 25.0	76.1 (25.4)	
Smoking status		
Never	72.6 (26.2)	> 0.10
Ex-smokers and current	78.9 (24.1)	
Alcohol consumption during last 30 days		
No	73.4 (25.9)	> 0.10
Yes	76.6 (25.4)	
Exercise during last 30 days		
No	74.0 (26.4)	> 0.10
Yes	74.8 (25.6)	
Structured exercise during last 30 days		
No	71.3 (25.4)	0.01
Yes	81.7 (25.6)	
Fruits and vegetable consumption during the last 7 days		
< 3 portions (daily)	75.9 (27.3)	> 0.10
≥ 3 portions (daily)	71.6 (22.4)	
Wheat bread/Cereals consumption during the last 7 days		
< 7 portions (weekly)	78.0 (26.1)	0.07
≥ 7 portions (weekly)	71.0 (24.4)	

*Student t-test

People that fulfilled the requirements for a good oral health indicator had a lower DMFS index (p-value<0.001). However, DMFS was not different among those with and without difficulty to chew (p-value>0.05) (Table 4.10).

Table 4.10. Average DMFS by oral health indicators*

	DMFS (SD)	p-value
Oral health indicator		
None	80.7 (24.3)	0.006
Any	77.7 (25.8)	
All	65.1 (24.2)	
Difficulty to chew		
No	73.7 (26.4)	> 0.10
Yes	76.7 (22.7)	

*Student t-test & one-way ANOVA when more than two categories

4.3.4. DS, FS and MS by demographic, lifestyle and oral health characteristics

Participants with diabetes had more decayed surfaces compared with those without diabetes (p-value<0.05). Female participants and those with more education had less decayed surfaces compared to their counterparts (p-value<0.05). No significant differences were found by age, monthly family income and health insurance type (p>0.05) (Table 4.11).

Table 4.11. Relative difference (RD) in the average DS* by demographic characteristics, n=184

	est. RD	95% CI	p-value
Sex			
Male	1.00	-	-
Female	0.34	0.22, 0.53	<0.001
Age in years			
≤ 78	1.00	-	-
> 78	1.50	0.95, 2.38	> 0.10
Education			
≤ 12	1.00	-	-
> 12	0.47	0.29, 0.78	0.003
Monthly family income			
< $1000	1.00	-	-
≥ $1000	1.14	0.71, 1.84	> 0.10
Health insurance type			
Government-sponsored (only)	1.00	-	-
Medicare (A, B &D)	1.00	0.45, 2.27	> 0.10
Private insurance	0.60	0.25, 1.40	> 0.10

*Use of simple Poisson regression model

Lifestyle characteristics and dietary variables were not significantly associated with decayed surfaces (p-value>0.05) (Table 4.12).

Table 4.12. Relative difference (RD) in the average of DS* by lifestyle characteristics, n=184

	est. RD	95% CI	p-value
BMI (kg/m^2)			
< 25.0	1.00	-	-
≥ 25.0	0.77	0.48, 1.24	> 0.10
Smoking status			
Never	1.00	-	-
Ex-smoker and current	1.55	0.96, 2.50	0.072
Alcohol consumption during the last 30 days			
No	1.00	-	-
Yes	0.75	0.42, 1.36	> 0.10
Exercise during the last 30 days			
No	1.00	-	-
Yes	0.77	0.48, 1.24	> 0.10
Structured exercise during the last 30 days			
No	1.00	-	-
Yes	0.88	0.52, 1.49	> 0.10
Fruits and vegetables consumption during the last 7 days			
< 3 portions (daily)	1.00	-	-
≥ 3 portions (daily)	0.95	0.57, 1.57	> 0.10
Wheat bread/Cereals consumption during the last 7 days			
< 7 portions	1.00	-	-
≥ 7 portions	0.90	0.56, 1.45	> 0.10

*Use of simple Poisson regression model

As expected, participants who had a good oral health indicator had less decayed surfaces (p-value<0.05). In addition, participants with difficulty to chew had more decayed surfaces compared to participants without difficulty to chew (p-value<0.05) (Table 4.13).

Table 4.13. Relative difference (RD) in the average of DS* by oral health indicators, n=184

	est. RD	95%CI	p-value
Oral health indicator			
None	1.00	-	-
Any	0.36	0.22, 0.58	<0.001
All	0.18	0.09, 0.35	<0.001
Difficulty to chew			
No	1.00	-	-
Yes	2.04	1.26, 3.33	0.004

*Use of Poisson regression model

Participants with diabetes had less filled surfaces compared with participants without diabetes (p-value<0.05). Furthermore, the number of filled surfaces was higher among participants with more years of education, higher monthly family income and private or Medicare insurance (p-value<0.05) (Table 4.14).

Table 4.14. Relative difference (RD) in the average of FS* by demographic characteristics, n=184

	est. RD	95% CI	p-value
Sex			
Male	1.00	-	-
Female	1.09	0.78, 1.51	> 0.10
Age in years			
≤ 78	1.00	-	-
> 78	1.07	0.79, 1.46	> 0.10
Education			
≤ 12	1.00	-	-
> 12	2.04	1.51, 2.76	<0.001
Monthly family income			
< $1000	1.00	-	-
≥ $1000	1.94	1.40, 2.69	<0.001
Health insurance type			
Government-sponsored (only)	1.00	-	-
Medicare (A, B &D)	2.87	1.09, 7.52	0.032
Private insurance	3.53	1.36, 9.21	0.010

*Use of simple Poisson regression model

Participants with a BMI≥25.0 kg/m^2 had significantly less filled surfaces compared to the participants with a lower BMI index (p-value<0.05). Those who reported alcohol consumption had more filled surfaces (est. RD 1.46; 95% CI: 1.05, 2.03). None of the dietary characteristics were significantly associated with filled surfaces (p-value>0.05) (Table 4.15).

Table 4.15. Relative difference (RD) in the average of FS* by lifestyle characteristics, n=184

	est. RD	95% CI	p-value
BMI (kg/m^2)			
<25.0	1.00	-	-
≥25.0	0.70	0.52, 0.96	0.024
Smoking status			
Never	1.00	-	-
Ex-smoker and current	1.07	0.76, 1.51	> 0.10
Alcohol Consumption during the last 30 days			
No	1.00	-	-
Yes	1.46	1.05, 2.03	0.023
Exercise during the last 30 days			
No	1.00	-	-
Yes	1.21	0.87, 1.68	> 0.10
Structured Exercise during the last 30 days			
No	1.00	-	-
Yes	1.33	0.97, 1.82	0.081
Fruits and vegetables consumption during the last 7 days			
< 3 portions (daily)	1.00	-	-
≥ 3 portions (daily)	1.21	0.88, 1.68	> 0.10
Wheat bread/Cereals consumption during the last 7 days			
< 7 portions (weekly)	1.00	-	-
≥ 7 portions (weekly)	1.03	0.75, 1.41	> 0.10

*Use of simple Poisson regression model

People with a good oral health indicator had significantly more filled surfaces (p-value>0.05), however, people with difficulty to chew had less filled surfaces than people without difficulty to chew (p-value<0.05) (Table 4.16).

Table 4.16. Relative difference (RD) in the average of FS* by oral health indicators, n=184

	est. RD	95% CI	p-value
Oral health indicator			
None	1.00	-	-
Any	3.22	1.50, 6.94	0.003
All	3.46	1.57, 7.59	0.002
Difficulty to chew			
No	1.00	-	-
Yes	0.59	0.37, 0.95	0.030

*Use of simple Poisson regression model

In the bivariate analysis with missing surfaces, the group with diabetes did not differ in the number of missing surfaces than those without diabetes (p-value>0.05). On the other hand, participants with more education had less missing surfaces (p-value>0.05) (Table 4.17).

Table 4.17. Prevalence Odds Ratio (POR) of MS* by demographic characteristics, n= 184

	est. POR	95% CI	p-value
Sex			
Male	1.00	-	-
Female	0.78	0.42, 1.45	> 0.10
Age in years			
≤ 78	1.00	-	-
> 78	1.30	0.73, 2.33	> 0.10
Education			
≤ 12	1.00	-	-
> 12	0.50	0.28, 0.90	0.022
Monthly family income			
< $1000	1.00	-	-
≥ $1000	0.64	0.35, 1.15	> 0.10
Health insurance type			
Government-sponsored (only)	1.00	-	-
Medicare (A, B &D)	0.39	0.11, 1.34	> 0.10
Private insurance and other	0.34	0.10, 1.16	0.086

*Use of simple logistic regression model

People who were overweight or obese had more missing surfaces compared with people with normal weight or underweight (p-value<0.05). The number of missing surfaces did not vary according to other lifestyles characteristics such as smoking, alcohol consumption and exercise

None of the dietary characteristics were significantly associated with missing surfaces (p-value>0.05) (Table 4.18).

Table 4.18. Prevalence Odds Ratio (POR) of MS* by lifestyle characteristics, n=184

	est. POR	95% CI	p-value
BMI (kg/m^2)			
< 25.0	1.00	-	-
≥ 25.0	2.25	1.20, 4.22	> 0.10
Smoking status			
Never	1.00	-	-
Ex-smoker and current	1.06	0.55, 2.03	> 0.10
Alcohol consumption during the last 30 days			
No	1.00	-	-
Yes	0.75	0.38, 1.49	> 0.10
Exercise during the last 30 days			
No	1.00	-	-
Yes	0.91	0.49, 1.67	> 0.10
Structured exercise during the last 30 days			
No	1.00	-	-
Yes	1.17	0.62, 2.21	> 0.10
Fruits and vegetables consumption during the last 7 days			
< 3 portions (daily)	1.00	-	-
≥ 3 portions (daily)	0.57	0.30, 1.08	0.087
Wheat bread/Cereals consumption during the last 7 days			
< 7 portions (weekly)	1.00	-	-
≥ 7 portions (weekly)	1.01	0.56, 1.83	0.04

*Use of simple logistic regression model

On the other hand, participants who had a good oral health indicator had less missing surfaces than their counterparts (p-value<0.05) (Table 4.19).

Table 4.19. Prevalence Odds Ratio (POR) in the average of MS* by oral health indicators

	est. POR	95% CI	p-value
Oral health indicator			
None	1.00	-	-
Any	0.57	0.22, 1.52	> 0.10
All	0.23	0.08, 0.67	0.007
Difficulty to chew			
No	1.00	-	-
Yes	1.45	0.68, 3.10	> 0.10

*Use of simple logistic regression model

4.3.5. Predictors of diabetes status

A simple logistic regression model was used to evaluate the association between diabetes status and socio-demographic, lifestyle and oral health variables, using as an operational criterion POR≥1.50. When the POR was under 1, the reciprocal result was taken in consideration (1/POR). The following variables were found to satisfy this threshold: sex, income, BMI, alcohol consumption, any exercise, structured exercise, vegetable consumption, and difficulty to chew (Tables 4.20-22).

Table 4.20 Prevalence Odds Ratio (POR) of diabetes status and demographic characteristics, n=184

	est. POR*	95% CI	p-value
Sex			
Male	1.00	-	-
Female	1.90	0.91, 3.96	0.089
Age in years			
≤ 78	1.00	-	-
> 78	0.87	0.43, 1.67	> 0.10
Education			
≤ 12	1.00	-	-
> 12	0.86	0.45, 1.64	> 0.10
Monthly family income			
< $1000	1.00	-	-
≥ $1000	0.63	0.33, 1.21	> 0.10
Health insurance type			
Government-sponsored (only)	1.00	-	-
Medicare (A, B &D)	1.80	0.46, 6.99	> 0.10
Private insurance	1.16	0.29, 4.59	> 0.10

* Unadjusted estimates of the Prevalence Odds Ratio (POR) from simple logistic regression

In addition to satisfy the criteria of POR≥1.50, participants who reported exercise during the last 30 days had a lower odds of having diabetes (POR = 0.35; p-value<0.05), whereas participants with difficulty to chew had a higher odds of having diabetes (POR = 2.27; p-value<0.05) Dietary characteristics were not significantly associated to diabetes status (Table 4.21-22).

Table 4.21. Prevalence Odds Ratio (POR) of diabetes status and lifestyle characteristics, n=184

	est. POR*	95% CI	p-value
BMI (kg/m^2)			
<25.0	1.00	-	-
≥25.0	1.91	0.91, 3.98	0.086
Smoking status			
Never	1.00	-	-
Ex-smoker and current	1.06	0.51, 2.19	> 0.10
Alcohol consumption during the last 30 days			
No	1.00	-	-
Yes	0.42	0.18, 1.03	0.058
Exercise during the last 30 days			
No	1.00	-	-
Yes	0.35	0.18, 0.69	0.003
Structured exercise during the last 30 days			
No	1.00	-	-
Yes	0.65	0.31, 1.37	> 0.10
Fruits consumption during the last 7 days			
< 3 portions (daily)	1.00	-	-
≥ 3 portions (daily)	0.58	0.28, 1.23	> 0.10
Wheat bread/Cereals consumption during the last 7 days			
< 7 portions (weekly)	1.00	-	-
≥ 7 portions (weekly)	0.83	0.43, 1.61	> 0.10

* Unadjusted estimates of the Prevalence Odds Ratio (POR) from simple logistic regression

Table 4.22. Prevalence Odds Ratio (POR) of diabetes status by oral health indicators, n=184

	est. POR*	95% CI	p-value
Oral health indicator			
None	1.00	-	-
Any	1.19	(0.43, 3.31)	> 0.10
All	0.76	(0.24, 2.37)	> 0.10
Difficulty to chew			
No	1.00	-	-
Yes	2.27	(1.04, 4.97)	0.040

* Unadjusted estimates of the Prevalence Odds Ratio (POR) from simple logistic regression

4.3.6. Evaluation of interaction in a linear regression model to explain DMFS

To evaluate DMFS all predictor variables were considered categorical. Variables included in the model were sex, age and smoking status. The assessment of interaction terms between predictors were performed using the log-likelihood ratio test. The interaction terms with sufficient numbers to evaluate interaction were included. The results showed absence of significant interaction terms (p-value>0.10) (Table 4.23).

Table 4.23 Assessment of interaction terms to evaluate DMFS index

	-2 log likelihood	Degrees of freedom
Full model: DMFS = Diabetes + Sex + Age + Smoking status + Diabetes*Sex + Diabetes*Age + Diabetes*Smoking status	-853.5164826	176
Reduce model: DMFS = Diabetes + Sex + Age + Smoking status	-854.6367032	179
Difference between models (χ^2)	2.24 p-value>0.10	3

4.3.7. Evaluation of interaction in a Poisson regression model to explain DS

To evaluate DS all predictor variables were considered categorical. Variables included in the model were sex, age, difficulty to chew and smoking status. The results showed presence of significant interaction terms (p-value<0.05) (Table 4.24).

Table 4.24 Assessment of interaction terms to evaluate DS index

	-2 log likelihood	Degrees of freedom
Full model: DS = Diabetes + Sex + Age + Difficulty to chew + Smoking status + Diabetes*Sex + Diabetes*Age + Diabetes*Smoking status	-644.253209	175
Reduced model: DS = Diabetes + Sex + Age + Difficulty to chew + Smoking status	-661.3769235	178
Difference between models (χ^2)	34.25 p-value<0.001	3

The individual effect of each interaction term was evaluated using the log-likelihood ratio test, comparing the full model with a reduced model that excluded one of the interactions terms. If the p-value from the log-likelihood ratio test was less than 0.05, then the effect of the interaction term on the model was considered significant. The results indicated that the interaction term between diabetes sex and smoking status were statistically significant.

4.3.8. Evaluation of interaction in a Poisson regression model to explain FS

Variables included in the model were sex, age, income, BMI, alcohol consumption, difficulty to chew and smoking status. However, data on alcohol consumption was scarce, because only 7 participants with diabetes reported alcohol consumption. Therefore, this variable was not introduced in the multivariate model as the estimates could not be accurate because of the small numbers. The results showed presence of significant interaction terms (p-value<0.001) (Table 4.25).

Table 4.25 Assessment of interactions terms to evaluate FS index

	-2 log likelihood	Degrees of freedom
Full model: FS = Diabetes + Sex + Age + BMI + Income + Difficulty to chew + Smoking status + Diabetes*Sex + Diabetes*Age + Diabetes*Smoking status	-1562.901236	170
Reduced model: FS = Diabetes + Sex + Age + BMI + Income + Difficulty to chew + Smoking status	-1590.809602	173
Difference between models (χ^2)	55.82 p-value<0.001	3

The individual effect of each interaction term was evaluated using the log-likelihood ratio test, comparing the full model with a reduced model excluding one of the interactions terms. If the p-value from the log-likelihood ratio test was less than 0.05, then the effect of the interaction term on the model was considered significant. The results indicated that the interaction term between diabetes with age, sex and smoking status were statistically significant, although there were not sufficient numbers to evaluate in three subgroups. After a second interaction analysis with the interaction terms of diabetes with age and sex the results showed that only the interaction term of diabetes and age was statistically significant.

4.3.9. Evaluation of interaction in a logistic regression model to explain MS

The variables included in the model were sex, age, BMI and smoking status. To evaluate MS all predictor variables were considered categorical. The results showed absence of significant interaction terms (p-value>0.10) (Table 4.26).

Table 4.26 Assessment of interaction terms to evaluate MS index

	-2 log likelihood	Degrees of freedom
Full model: MS = Diabetes + Sex + Age + BMI + Smoking status+ Diabetes*Sex + Diabetes*Age + Diabetes* Smoking status	-120.25884	174
Reduced model: MS = Diabetes + Sex + Age+ BMI + Smoking status	-121.45466	177
Difference between models (χ^2)	2.39 p-value > 0.10	3

4.4. Multivariate analysis

4.4.1. Multiple linear regression model

The multiple linear regression model to explain the expected value of DMFS showed diabetes was not significantly associated (p-value>0.05) after adjusting for sex and age (Table 4.27).

Table 4.27 Average difference in DMFS (β) using a multiple linear regression model, n=184

	Unadjusted β †	95% CI †	Adjusted β ‡	95% CI ‡
Diabetes				
No	Reference	-	Reference	-
Yes	3.02	-5.29, 11.34	3.39	-4.94, 11.72
Sex				
Male	Reference	-	Reference	-
Female	-2.57	-10.48, 5.34	-1.13	-9.71, 7.45
Age in years				
≤ 78	Reference	-	Reference	-
> 78	8.11**	0.73, 15.51	7.81**	0.37, 15.25
Smoking status				
Never	Reference		Reference	-
Ex-smoker and current	6.31	-2.07, 14.70	5.02	-4.08, 14.12

†Unadjusted estimates from simple linear regression model.
‡Estimates are adjusted by age, sex and smoking status
** p-value < 0.05

4.4.2. Multiple Poisson regression model

The model suggests that male participants had a significantly higher risk for decayed surfaces among non-smokers (est. RD = 4.43; 95% CI: 2.08, 9.40) and ex- and current smokers (est. RD = 2.23; 95% CI: 1.09, 4.56), after adjusting for age and difficulty to chew. However, this was not true among female participants (p-value>0.05) (Tables 4.28-29).

Table 4.28. Multiple Poisson regression model to assess the average DS, n=184

	Unadjusted β †	95% CI †	Adjusted β ‡	95% CI ‡
Diabetes				
No	Reference	-	Reference	-
Yes	0.62**	0.16, 1.08	1.49**	0.74, 2.24
Sex				
Male	Reference	-	Reference	-
Female	-1.08**	-1.53, -0.64	-0.81**	-1.40, -0.22
Age in years				
≤ 78	Reference	-	Reference	-
> 78	0.41*	-0.05, 0.87	0.39*	-0.04, 0.82
Difficulty to chew				
No	Reference	-	Reference	-
Yes	0.71**	0.22, 1.20	0.62	0.14, 1.10
Smoking status				
Never	Reference	-	Reference	-
Ex-smoker and current	0.44*	-0.04, 0.92	0.07	-0.54, 0.68
Interaction term				
Diabetes and sex	-	-	-1.17	-2.13, -0.20
Interaction term				
Diabetes and smoking status	-	-	-0.69	-1.68, -0.31

† Unadjusted estimates from simple Poisson regression model.

‡ Estimates are adjusted by sex, age, difficulty to chew, diabetes and sex interaction and diabetes and smoking status interaction.

* 0.05 < p-value < 0.10

** p-value < 0.05

Table 4.29. Relative difference (RD) in the average of DS using a multiple Poisson regression model by sex and smoking habit

	RD*	95% CI*	p-value*
Males (n= 61)			
Non-Smoker (n=30)	4.43	2.08, 9.40	<0.001
Ex- and current smoker (n=31)	2.23	1.09, 4.56	0.028
Females (n= 123)			
Non-smoker (n=105)	1.38	0.70, 2.71	>0.10
Ex-and current smoker (n=18)	0.70	0.23, 2.14	>0.10

*Estimates are adjusted by age and difficulty to chew

The multivariate analysis performed to explain filled surfaces (FS) was constructed by the variables significantly associated with both filled surfaces and diabetes in addition to the variables sex, age and smoking status. The interaction terms for diabetes and age was included in the model (Table 4.30). Based on this model, the estimates for subgroups were calculated (Table 4.31). The results suggested that individuals aged 78 years and younger with diabetes did not significantly differ regarding filled surfaces compared to participants without diabetes, after adjusting for sex, income, BMI, difficulty to chew and smoking status (p-value>0.05). However, participants with diabetes who were older than 78 years had marginally significantly less filled surfaces than participants without diabetes (est. RD = 0.56; 95% CI: 0.29, 1.06) (Tables 4.30-31).

Table 4.30 Multiple Poisson regression model to assess the average FS, n=181

	Unadjusted β †	95% CI †	Adjusted β ‡	95% CI ‡
Diabetes				
No	Reference	-	Reference	-
Yes	-0.48**	-0.86, -0.09	-0.17	-0.63, -0.29
Sex				
Male	Reference	-	Reference	-
Female	0.06	-0.27, 0.39	0.33*	-0.01, 0.67
Age in years				
≤ 78	Reference	-	Reference	-
> 78	0.05	-0.26, 0.36	0.12	-0.20, 0.44
Monthly family income				
< $1000	Reference	-	Reference	-
≥ $1000	0.67**	0.34, 0.99	0.62**	0.29, 0.96

	Unadjusted β †	95% CI †	Adjusted β ‡	95% CI ‡
BMI (kg/m^2)				
<25.0	Reference	-	Reference	-
≥25.0	-0.36**	-0.67, -0.05	-0.37	-0.68, -0.07
Difficulty to chew				
No	Reference	-	Reference	-
Yes	-0.52**	-1.00, -0.05	-0.45*	-0.91, -0.01
Smoking status				
Never	Reference	-	Reference	-
Ex-smoker and current	0.07	-0.27, 0.41	0.14	-0.22, 0.50
Interaction term				
Diabetes and age	-	-	-0.40	-1.19, 0.38

† Unadjusted estimates from simple Poisson regression model.
‡ Estimates are adjusted by sex, age, family income, BMI, difficulty to chew, smoking status, and diabetes and age interaction
* 0.05 < p-value < 0.10
**p-value < 0.05

Table 4.31. Relative difference (RD) in the average of FS using a multiple Poisson regression model by age

Age	RD *	95% CI*	p-value*
≤ 78 years (n = 99)	0.84	(0.53, 1.33)	> 0.10
> 78 years (n = 82)	0.55	(0.29, 1.04)	0.067

*Estimates are adjusted by sex, family income, BMI, difficulty to chew and smoking status

4.4.3. Multiple logistic regression model

In the multiple logistic regression model used to explain missing surfaces (MS), diabetes status was not significantly associated with missing surfaces (p-value > 0.05) after adjusting for sex, age, BMI and smoking status (Table 4.32).

Table 4.32. Prevalence Odds Ratio (POR) of MS using a multiple logistic regression model, n=183

	Crude POR†	95% CI†	Adjusted POR ‡	95% CI ‡
Diabetes				
No	1.00	-	1.00	-
Yes	1.53	0.80, 2.96	1.51	0.76, 2.99
Sex				
Male	1.00	-	1.00	-
Female	0.79	0.43, 1.47	0.65	0.32, 1.31
Age in years				
≤ 78	1.00	-	1.00	-
> 78	1.33	0.74, 2.39	1.52	0.83, 2.80
BMI (kg/m^2)				
< 25.0	1.00	-	1.00	-
≥ 25.0	2.25**	1.20, 4.22	2.41**	1.25, 4.65
Smoking status				
Never	1.00	-	1.00	-
Ex-smoker and current	1.06	0.55, 2.03	0.72	0.34, 1.53

† Unadjusted estimates from simple logistic regression model.
‡Estimates are adjusted by sex, age, BMI and smoking status
**p-value < 0.05

CHAPTER 5: DISCUSSION

This chapter discusses the most relevant findings from the study and the conclusions. In addition, the limitations and strengths for this study are identified and recommendations are suggested for future studies.

5.1. Discussion

This study evaluated the magnitude of association between dental caries and diabetes mellitus among adults 70 years and older living in the Metropolitan area of San Juan, Puerto Rico. Variables of interest were also evaluated for potential significance in the association between dental caries and diabetes. In overall, no significant differences were found in the DMFS between the participants with and without diabetes. This is consistent with other studies that also compared dental caries among people with diabetes and without diabetes, including a longitudinal study of two years that did not find any overall differences between the two groups (Siudikiene et al., 2008; Moore et al., 2001; Collin et al, 1998; Cherry-Peppers et al., 1993). On the other hand, our results are contrary to other studies evaluating dental caries and diabetes that found a higher DMFS index in that population (Albrecht et al., 1988; Ilguy et al., 2007; Jones et al., 1992)

We found significantly more decayed surfaces in the group with diabetes among men, but no significant difference among women. Other studies have also found people with diabetes having more decayed surfaces or teeth, although these studies have not reported differences across sex groups (Lin et al., 1999; Cherry-Peppers et al., 1993). It has been suggested that females have a higher calorie intake and more meal frequency (Moore et al., 2001) and a lower salivary flow than men (Närhi et al., 1996), but these explanations point towards women having a higher risk for dental caries. Therefore, a better explanation would be cultural differences in terms of oral hygiene between sex groups, as in general (people with and without diabetes) men had more decayed teeth compared to women (Yari Valle, unpublished data). In addition, a longitudinal study, as well as cross-sectional study, found higher decayed surfaces among people with diabetes that had worse metabolic control (HbA_{IC}>8%) compared to those with good metabolic control, and this might be an explanation of the more decayed teeth in our results (Lin et al., 1999; Twetman et al., 2002). However, this could not be verified in our study because the diabetes was self-reported and glycemic state was not available.

The participants with diabetes had significantly less filled surfaces compared to people without diabetes in both age groups. Two other studies have suggested that people with diabetes have less filled surfaces (Lin et al., 1999; Albrecht et al., 1988). This could be explained by people with diabetes having more missing teeth due to periodontal disease and already lost their teeth with fillings. Indeed, among our participants a higher percent of the people with diabetes had severe periodontitis (Sona Tumanyan, unpublished data). Another explanation might be that people without diabetes get more dental care and intervention of decayed teeth, although we did not find any differences between the groups in terms of dental visits. On the other hand, it has been suggested that there could be a tendency of dentists taking out decayed teeth instead of doing restorations if people with diabetes have more severe caries or in order to prevent progression in compromised patients (Jones et al., 1992; Johnson et al., 1993). These results contrast the finding of other studies who suggests the amount of filled surfaces is similar across diabetes status (Bacic et al., 1999, Ilguy et al., 2007; Siudikiene et al., 2008; Collin et al., 2001; Cherry-Peepers et al., 1993; Jones et al., 1992).

In our study group the people with diabetes had similar amount of missing surfaces compared to those without diabetes. Although, there are two studies that are consistent with our data (Siudikiene et al., 2008; Jones et al., 1992), most of the studies evaluating dental caries and diabetes have found that people with diabetes have a higher number of missing surfaces or teeth compared to people without diabetes (Tavares et al., 1991; Albrecht et al., 1988; Bacic et al., 1989; Ilguy et al., 2007; Hintao et al., 2007; Moore et al., 2001), which is explained by the fact that people with diabetes are more prone to periodontal disease and therefore lose more teeth than people without diabetes (Taylor et al., 2004; Mealey & Oates, 2006; Silvestre et al., 2009).

Some studies have chosen to exclude the missing teeth from the DMFS index, because the reasons for extraction of the teeth were unknown (Moore et al, 2001; Twetman et al., 2002). However, in this study there was a distinction made at the time of dental exam, between those teeth missing due to disease (i.e. caries and periodontal disease) and those missing because of other reasons (i.e. trauma). Only the teeth missing due to disease were counted in the DMFS index and therefore the number of missing teeth is not overestimated by other factors affecting the loss of teeth.

The results regarding root caries and root restorations suggest that there were no significant differences between the groups with and without diabetes. There have been different results across the literature and among the six studies that evaluate root caries (Tavares et al., 1991; Lin et al., 1999; Collin et al., 1998; Närhi et al., 1996; Hintao et al., 2007; Moore et al., 2001), three of them found no significant differences across diabetes status and are consistent with our findings (Lin et al., 1999; Collin et al., 1998; Närhi et al., 1996). We only looked at the prevalence of root caries and root restorations, so it is hard to know if the outcome would have been different if the number of decayed and filled root surfaces were available.

Nearly 18% of the participants had difficulty to chew, which could be an indicator of oral health in general, because it affects the ability to eat and well-being of the person. This variable was associated with decayed and filled surfaces and it is very reasonable to think that participants with decayed surfaces might have associated inflammation or pain which will affect their ability to chew.

We also found BMI to be associated with both diabetes and dental caries, specifically for filled and missing surfaces. First of all, BMI is a risk factor for diabetes and people who are overweight or obese are prone to develop diabetes if the weight condition persists (ADA, 2009). Among our participants, most of them were overweight or obese (66%). The relationship between caries and BMI could be due to common risk factors, such as dietary habits, but this has not been studied thoroughly. In the US, the obesity is also related to low SES, mediated by the low-cost of food particularly high in fat and sugars. In a study among children, BMI predicted caries experience (DS>1) (OR = 3.02, 95% CI: 1.46-6.25) (Marshall et al., 2007). However, BMI has both genetic and environmental components, which makes it difficult to distinguish the contribution of each of them in a cross-sectional study.

Insurance and income are two related factors, because both of them could be barriers for access to dental care. In our study, income but not insurance was associated with dental caries and diabetes. A publication from PREHCO 2002-2003 (Palloni et al., 2003) reveals that 43% of participants that visited the dentist had full cover from their insurances and did not have to pay, whereas the other 57% had to pay from their own pocket, although most of them did not pay more than $200.00. In our sample, the median monthly income was $1,043 and provides an idea of the difficulties to pay out of pocket. Therefore, both income and insurance could be barriers of oral health intervention.

There were a few indicators that were expected to be associated with the oral health outcomes in this study but were not, such as dental visits, use of dental floss and mouthwash.

The proportion of participants that visited the dentist, used dental floss and mouthwash was similar among participants with diabetes and without diabetes. Even so, it is important to point out that these variables are an integral part of the oral hygiene recommended to prevent the development of dental caries and maintain a good oral health (Petersen, 2005). One study found these variables to be significant in predicting dental caries (Moore et al., 2001).

5.2. Conclusion

In conclusion, this study describes the oral health status of older adults with diabetes in San Juan, Puerto Rico. The major results were that men with diabetes had a significant higher risk of decayed surfaces than those without diabetes. However, this difference was not significant among women. Thus, participants with diabetes have more decayed surfaces with small differences across sex groups. Furthermore, participants with diabetes had significantly less filled surfaces compare to those without diabetes and this could be because of people with diabetes having more missing surfaces due to pre-existing periodontal disease and already lost teeth with filled surfaces. Our results indicated no significant differences in missing surfaces, or root caries and root restorations between the participants with and without diabetes. As of today, there are only two longitudinal analyses that have evaluated the association between diabetes and caries among children with type 1 diabetes. Therefore, future longitudinal studies are needed to better understand the association between type 2 diabetes and caries experience among adults.

5.3. Strengths

A strength of this study is that the oral exam was done on the complete mouth, which assures the outcome of caries experience of the participants. In addition, the examiners were trained and standardized by the NHANES principal examiner Dr. Bruce A. Dye.

5.4. Limitations

This study has some limitations that have to be described. First of all, this study is a cross-sectional and because of its design it is not able to establish any temporal sequence in the association between diabetes and caries (Gordis, 2004). A second limitation was the small study group which may have affected the statistical power to detect the association between dental caries and diabetes, especially in subgroups. Even so, our results were very similar to other studies with larger populations.

Another limitation is that this study only represents adults older than 70 years and has no representation of the population between 65 and 70 years. Therefore, elderly adults with fewer health conditions and better oral health might have been excluded by this age criteria. On the other hand, it could also have excluded adults with severe diabetes who died before reaching the age of 70.

Diabetes status was ascertained by self-report and not confirmed by standardized blood tests. In this regard, the prevalence of diabetes in our study (28%) is similar to the prevalence reported by the BRFSS during 2003-2005, time period when the PREHCO study was conducted. However, taking into account that some adults might not know about their diabetes status because of lack of symptoms, the proportion of subjects with diabetes might be underestimated.

In this study we used the DMFS index as an indicator of caries experience. Although, this index has been universally accepted, some limitations include that in this index all the missing teeth are considered as having experienced caries, decayed and filled teeth are given the same importance and finally, it gives the same weight to untreated caries, extraction and restoration (Benigeri et al., 1998). To our knowledge, no other index has been developed that overcomes these limitations. (Benigeri et al., 1998). Another limitation concerns the potential for nonresponse bias; however, participants differed from nonparticipants only by sex and health insurance type. Finally, because there were some exclusion criteria applied and the response rate was 47%, the generalization of the results from this study is limited. Despite these limitations, this study provides an important insight of the oral health status in the older adults with diabetes living in San Juan, Puerto Rico.

5.5. Recommendations

According to our results several recommendations are made. First, oral health interventions are underscored among older people with diabetes due to an increase in decayed surfaces. In addition to access to dental care services, elderly Puerto Ricans may be experiencing other barriers such as fear of the dentist, long waiting times, and transportation difficulties, limiting their ability to visit a dentist. Second, it is important for oral health interventions to give oral health education among the population with diabetes in order to prevent caries that might affect their oral health in older age. Furthermore, the population with diabetes should be encouraged to attend regular dentist check-ups every six months to prevent caries development.

It is also essential to increase awareness among the dentists about the potential link between dental caries and diabetes for an improved prevention of oral health complications among the population with diabetes. As long as the health care system permits it is recommended that the dentist and the primary care doctor collaborate for exchange of information and prevention because of the association between oral health and systemic diseases. Finally, patients with diabetes should be encouraged to inform their dentist about their chronic conditions in order to receive more individualized care.

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